



DELAWARE RIVER BASIN NATIONAL WATER QUALITY MONITORING NETWORK PILOT STUDY FINAL REPORT

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1. Overview of study area

The Delaware River Basin (Fig. 1) encompasses 13,539 square miles (mi²) and contains one of the longest un-dammed rivers in the United States, extending 330 miles from the confluence of its East and West branches at Hancock, N.Y. to the mouth of Delaware Bay. Significant amounts of historical and current water-quality monitoring (physical, chemical, and biological) has been conducted in the watersheds, estuaries, near-shore, and off-shore parts of the basin by Federal, State, local, private, and academic entities.

Basin hydrologic features include:

- 216 tributaries within New York, Pennsylvania, New Jersey and Delaware.
- One the world's largest freshwater tidal estuaries.
- The 782 mi² Delaware Bay
- Parts of Coastal, Piedmont, New England, Valley and Ridge, Appalachian Plateau provinces.
- Recent flooding on Delaware River main stem and tributaries.

Land use, population, and water use statistics:

- Includes about 9% urban, 24% agricultural, 60% forested, and 5% wetlands.
- Nearly 15 million people (about 5% of the nation's population) rely on the waters of the Basin for drinking water which includes about 7 million people in New York City and northern New Jersey who live outside the Basin.
- World's largest freshwater port complex and one of the Nation's largest oil/container ports.
- Recreation and beach activities especially on the Atlantic Coasts of NJ and DE.

Ecological features:

- The Delaware River and Estuary are national environmental assets, including a wide range of natural habitats and wildlife such as 185 vegetation community types and 35 ecological systems. Three-quarters of the non-tidal river (about 150 miles or 241 kilometers) has been included in the National Wild and Scenic Rivers System.
- The Delaware Estuary contains more that 405,000 acres of wetlands;
- The watershed is home to more than 200 fish species including important anadromous and euryhaline fishes such as the American shad, striped bass, and sturgeon.
- The watershed provides habitat for federally protected endangered species such as dwarf wedgemussel, short-nose sturgeon, bald eagles, and bog turtles.

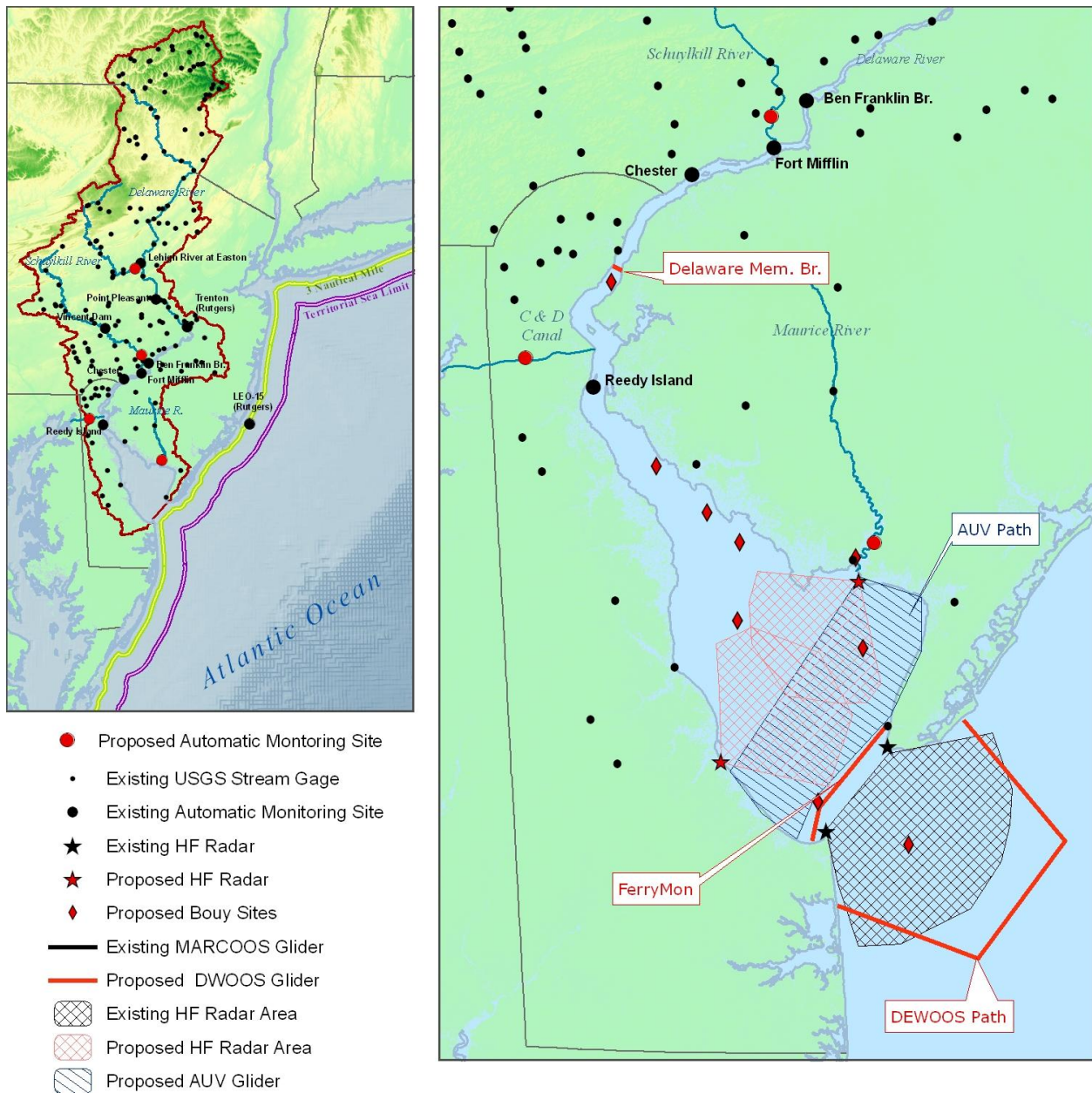


Figure 1.1. The Delaware Estuary with current and proposed observing system components. Insert shows drainage basin and adjacent continental shelf region with glider path.

2. Major management issues

Background

A. Estuary Science Conference: In early 2005, a Delaware Estuary Science Conference was convened to bring researchers, resource managers and other interested parties together to summarize the current state of science and identify and prioritize science and management needs for the Estuary. The two-part science and management event was organized by the Partnership for the Delaware Estuary and attracted attendees from government agencies, academia, industry and non-governmental organizations. More than 250 scientists, managers and science-interested people met to deliver more than 130 presentations. (For further information on this see: Kreeger, D., R. Tudor, J. Sharp, S. Kilham, D. Soeder, M. Maxwell-Doyle, J. Kraeuter, D. Frizzera, J. Hameedi and C. Collier. 2006. White paper on the status and needs of science in the Delaware Estuary. Partnership for the Delaware Estuary. 72 pp. <http://www.delawareestuary.org/scienceandresearch/datasetsandreports/>)

The output of this conference was a science to management “blueprint” that divided management issues into both technical and operational components.

The **top ten technical needs** that were identified for advancing science and management of the Delaware Estuary ecosystem are, with top priority listed first: 1) **contaminants** (e.g., forms, sources, fates & effects of different classes); 2) **tidal wetlands** (e.g., status and trends of different types); 3) ecologically significant species and **critical habitats** (e.g., benthos, reefs, horseshoe crabs); 4) **ecological flows** (e.g., effects of freshwater inflow on salt balance and biota); 5) **physical-chemical-biological linkages** (e.g., effects of sediment budget on toxics and biota); 6) **food web dynamics** (e.g. identification and quantification of dominant trophic interactions); 7) **nutrients** (e.g., forms, concentrations and relative balance); 8) **ecosystem functions** (e.g. economic valuation of ecosystem services); 9) habitat restoration and enhancement; and 10) invasive species (e.g., monitoring and control).

The **top six operational needs** are : 1) better linkages between science and management; 2) a comprehensive conceptual framework describing key elements of the estuary ecosystem; 3) implementation of ecosystem management approaches; 4) **expansion of the monitoring infrastructure with links to indicators and goals**; 5) **better data coordination, compatibility, quality, sharing, access and archiving**; and 6) **stronger public education programs** that broaden understanding of the defining traits and issues in the Delaware Estuary.

B. NOAA-Supported Workshop: In late 2005, a NOAA-supported workshop focused on water quality monitoring and data-management issues in the Mid-Atlantic Ocean Observation Regional Association (MACOORA) was convened at Rutgers University. The workshop emphasized the Delaware River Basin drainage and involved 51 invited scientists and managers (Federal/State/local/academia) with expertise in water-quality monitoring in the region. The primary goal of the effort was to identify key management issues and related scientific questions that could be addressed by a comprehensive IOOS-NWQMN infrastructure. Those invited were carefully selected to cover expertise in monitoring in a 3 x 3 matrix related to (1) physical, (2) chemical, and (3) biological parameters in (1) watersheds above the head of tide, (2) estuaries, and (3) coastal areas.

Abstracts and results of facilitated breakout groups from the workshop are presented in the Proceedings from the NOAA-Supported Workshop Linking Elements of the Integrated Ocean Observing System (IOOS) with the Planned National Water Quality Monitoring Network (Rowe, Hameedi, and Weinstein, eds. in press). (<http://marine.rutgers.edu/cool/coolresults/2005/>) Recommendations of the workshop included: (1) a need for improved water-quality data exchange among the various groups; and (2) the Delaware River Basin would serve as an ideal candidate for a Pilot study to test the design of the NMN.

Management Issues and Monitoring Needs

As a direct result of the coordination processes above, the science and management community of the Delaware watershed and estuary identified the following specific management issues:

- Maintaining freshwater quantity and quality
- Assuring public health (beach contamination and drinking water/seafood safety)
- Potential impacts of nitrogen overload and nutrient imbalance in the estuary, including factors affecting dissolved oxygen concentration in the estuarine and coastal areas
- Assessing impacts of dredging, including bottom and marshland erosion and sediment removal from non-dredged areas
- Loss of habitat and population status of key species (e.g., Eastern oyster, horseshoe crab, and American shad)
- Assessing ecological risks of accidental discharges of oil and other chemical spills
- Environmental sources, transport and effects of contaminants of concern in the region (e.g., polychlorinated biphenyls (PCBs), mercury, and contaminants of emerging concern such as pharmaceuticals, flame retardant chemicals, stain repellent chemicals, and industrial detergents)
- Federal and State agencies have already collected a tremendous amount of data. Finding the data required can be difficult, therefore better methods are needed to access and deliver data.
- Develop ways to utilize probabilistic monitoring with discrete monitoring in an effective and complementary manner.
- In situ monitors (real-time, continuous) are not as expensive as in the past. This is one way to include new technologies to the manager's tool kit.
- The Delaware Estuary is fundamentally defined by its extensive fresh, brackish and saltwater marshes. The major goal of management should be to maintain and conserve the health, function and biota of the wetlands.
- The major exchange points of the Delaware Estuary include watershed inputs (Delaware River), urban inputs (Philadelphia and Camden), exchange with the Chesapeake and Delaware Canal, and exchange with the adjacent shelf.

3. Inventory

Delaware River and Estuary Profile

The Delaware Estuary, with its 50-mile long tidal freshwater Delaware River and the Delaware Bay, is one of the most important estuaries in the Nation. The Delaware River watershed is one of the largest drinking water supplies in the US serving both New York City and Philadelphia.

The urban region of the tidal river consists of the greater Philadelphia municipal area, the fourth largest in the country. This urban region was, by most standards, one of the “most-polluted” rivers in the country in the past and has undergone a very successful water quality improvement over the last few decades. Highlights of some monitoring efforts are highlighted to show the extent of monitoring in the Delaware Basin.

There is a good, consistent, monitoring database extending almost 40 years that helps document the past improvements and provides metrics for assessing future changes. Since the Delaware Estuary is dominated by a single major river, with the second largest water input also coming into the freshwater region, it is possible to monitor much of the physical control of the estuary with well-established gauging stations. New Jersey, Pennsylvania, and Delaware, as the three states along the estuary, have a long-standing record of cooperative management of the estuarine resources. Academic research efforts in the river and bay have been relative modest in breadth but studies of river conditions, estuarine microbial biogeochemistry, and bay oyster and fish populations have long time consistent histories.

Currently there are numerous major Federal, State, Interstate, private, and academic monitoring programs and data management activities within the Delaware Basin (Table 1). These programs focus on physical, chemical, and biological water-quality monitoring in watersheds, estuaries, coastal areas (nearshore, offshore), atmosphere, wetlands, and ground water. These monitoring networks are related to: (1) freshwater inflow; (2) water use; (3) dissolved oxygen; (4) nutrients and biogeochemical processes; (5) contaminants; (6) estuarine sediments and beach processes; (7) transportation and port security; and (7) impact of climate change on sea-level rise.

Some examples of monitoring in the Delaware Basin area are noted below:

- Recent studies of the sedimentology of the estuary by the University of Delaware and the Delaware River Basin Commission have provided valuable insights on sediment transport and the impact of dredging. These cooperative studies will continue in the next two years with extensive sediment coring in the saltwater and freshwater marshes fringing the system.
- The University of Delaware and the DRBC have collected significant historical data to determine trends over time for dissolved oxygen and nutrients in the Delaware Estuary “Boat Run” monitoring stations below Philadelphia sampled regularly since 1967. Results show the increase in dissolved oxygen over time as a result of the improvements in point source discharges in the basin. (<http://www.ocean.udel.edu/cms/jsharp/CruiseDatabase.htm>)
- Recently, new technologies have allowed for continuous monitoring of water-quality characteristics at various locations in the basin. The USGS operates over 20 continuous real-time water-quality monitoring stations (<http://waterdata.usgs.gov/nwis/current/?type=quality>) in the Delaware Basin (pH, temperature, conductance, density, dissolved oxygen, turbidity) for at least part of the year and all year at the Delaware River at Trenton.
- The Rutgers University Institute of Marine and Coastal Sciences (ICMS) operates a fleet of autonomous underwater vehicles (AUVs) that collect water-quality data (temperature, salinity, density) in real-time in several sites offshore of the Atlantic Coast and world-wide (<http://marine.rutgers.edu/cool/auvs/>). Two dimensional patterns of water density provide insight as to the variability of water quality with depth and distance away from shore.

A summary of monitoring programs indexed by resource compartment and level of effort is provided at Table 2.

Table 1. Federal and non-Federal monitoring programs active in the Delaware River Basin.

Agency (Abbreviation)		Web address	Contact
Federal Monitoring Program			
U.S. Geological Survey Water Science Centers	USGS-NJWSC USGS-PAWSC USGS-NYWSC	http://nj.usgs.gov/ http://pa.water.usgs.gov/ http://ny.water.usgs.gov/	Richard Kropp Patricia Lietman Willie Rodriguez
USGS National Water Quality Assessment Program (NAWQA)		http://nj.usgs.gov/nawqa/delr/	Jeff Fischer
U.S. Environmental Protection Agency Ecology Division (AED)		http://www.epa.gov/aed/	John Garber
USEPA National Estuary Program (NEP) Center for Inland Bays		http://www.inlandbays.org/	
U.S. Environmental Protection Agency Region 2 (USEPA-R2)		http://www.epa.gov/region2/	John Kushwara
U.S. Environmental Protection Agency Region 3 (USEPA-R3)		http://www.epa.gov/region03/	Larry Merrill
USEPA Atlantic Ecology Division/ORD (USEPA-AED)		http://www.epa.gov/aed/index.html	Henry Walker
DE and Nat. Oceanographic and Atmospheric Admin (NOAA/NEERS)		http://neris.noaa.gov/	R. Scarborough
NOAA PORTS Delaware River/Bay		http://co-ops.nos.noaa.gov/dbports/	
National Park Service (NPS)		http://www.nps.gov/upde/	Joseph DiBello
Natural Resources Conservation Service (NRCS-NJ)		http://www.nj.nrcs.usda.gov/	Tom Drewes
U.S. Fish and Wildlife Service (USFWS)		http://www.fws.gov/northeast/njfieldoffice/	Clifford Day
U.S. Army Corps of Engineers Philadelphia District		http://www.nap.usace.army.mil/	
Non-Federal Monitoring Programs			
National Atmospheric Deposition Program (NADP)		http://nadp.sws.uiuc.edu/	
Delaware River Basin Commission (DRBC)		http://www.state.nj.us/drbc/	Robert Tudor
New Jersey Department of Environmental Protection (NJDEP)		http://www.state.nj.us/dep/	Leslie McGeorge Robert Connell
New Jersey Water Monitoring Coordinating Council (NJWMCC)		http://www.state.nj.us/dep/wms/wmcc/home.html	
Delaware Depart of Natural Resources and Environmental Control (DENREC)		http://www.dnrec.delaware.gov/	R. Scarborough
Partnership for the Delaware Estuary (PDE)		http://www.delawareestuary.org/	Danielle Kreeger
Pennsylvania Department of Environmental Protection (PADEP)		http://www.depweb.state.pa.us/dep/	James Newbold
Delaware Environmental Observing System (DEOS)		http://www.deos.udel.edu/	
Rutgers University Institute of Marine and Coastal Sciences (IMCS)		http://marine.rutgers.edu/cool	Scott Glenn
Univ. of Delaware		http://www.ocean.udel.edu/cms/jsharp/CruiseDatabase.htm	Jonathan Sharp
Sea Grant and Marine Sciences Consortium		http://www.njmsc.org/Sea_Grant http://www.njmsc.org/	Mike Weinstein
Drexel University			Mike Piasecki

Table 2. Delaware Pilot Inventory Summary Table: Monitoring Organizations and Resource Components Monitored

“++” indicates major monitoring effort

“+” indicates minor monitoring effort

“NA” indicates no monitoring effort underway

Org	Estuary/ embayment	Near- shore coast	Off- shore coast	Rivers	Ground water	Atm Dep	Wet land	Beaches
USEPA	+	++	+	++	N/A	N/A	N/A	+
NOAA	+	+	++	N/A	N/A	N/A	+	N/A
USGS	+	N/A	N/A	++	++	N/A	+	N/A
COE	+	N/A	N/A	+	+	NA	N/A	N/A
DE DNREC	+	+	N/A	+	+	++	+	+
PADEP	+	N/A	N/A	+	+	+	+	+
NJDEP	++	+	N/A	++	++	+	N/A	++
UDEL	++	+	+	N/A	N/A	+	N/A	N/A
RUTGERS	+	++	++	+	N/A	+	N/A	N/A
DRBC	++	N/A	N/A	++	+	+	N/A	N/A
Bay/Estuary Program	+	N/A	N/A	+	N/A	N/A	+	N/A
PHILA.	+	N/A	N/A	++	+	+	+	N/A
CAMDEN	N/A	N/A	N/A	++	+	+	N/A	N/A
POWER UTIL.	++	N/A	N/A	++	N/A	N/A	++	N/A

Note: Major Cost is over \$1.0 million. Minor Cost is less than \$1.0 million. These funds would be cumulative over a 5 year period.

4. Data management issues

We have begun development of a prototype for the Delaware Estuary-to-Watershed-to-Ocean Observing System (DEWOOS). Its goal is to be a functionally working *prototype* for a total watershed and coastal environmental (meteorological, hydrological, oceanographic) monitoring system that can be readily ported to other watersheds in the mid-Atlantic (MACOORA) or other national implementations (see figure below). It is based on the existing DEOS infrastructure (Delaware Environmental Observing System — www.deos.udel.edu) in that it uses the Oracle[®] database structure and ODD-DIVAS[®] tools for data display. However, we have begun the incorporation of a true GIS-based visualization platform using ESRI's ArcGIS Server 9.2 interface, rather than the current use of Google Maps[®] for data location and display. This will allow for a more direct application (not requiring overlays to be gathered from Google Maps[®]) and better control of the final appearance. More importantly, however, this will allow us to analyze and display raster (*i.e.*, gridded) data so that observations from satellite, radar (weather and wave conditions), interpolated or computed fields (*e.g.*, evapotranspiration or atmospheric humidity), and even model output can be easily incorporated.

To date, we have begun the following tasks:

- 1) Data have been incorporated from the DEOS network, the USGS Stream Gauge Network, and the NWS first-order weather station network for Delaware, southeastern Pennsylvania, and southern New Jersey. We will complete the inclusion of data from these three networks for the entire Delaware River Basin and also include available buoy data.
- 2) Construction of the website for highlighting the data available and providing a link to the GIS visualization component has begun. The homepage is currently available (see attached figures at Appendix 2) and we are working on additional pages of information.
- 3) GIS overlays have been obtained from Penn State University and the functionality of the GIS is well along (see attached figures). We still have to connect it to the server so it will be accessible from the site webpage.

Table 3. Data Access, Management and Delivery

Number of Programs and Percentage of all programs with specific attributes relative to data access, management, and delivery. Items in boldface type are the most desired characteristics of a Network data system. Percentage calculations reflect consideration of 16 representative programs that are part of pre-cursor Delaware Pilot data portal system known as DEOS. This system is currently being upgraded and expanded in scope to encompass the entire Delaware River Basin and all the data providers listed in Table 1. The expanded system, known as the Delaware Estuary Watershed to Ocean Observing System (DEWOOS), will be a ‘one-stop shop’ for environmental data in the Delaware River Basin from headwaters to coastal ocean.

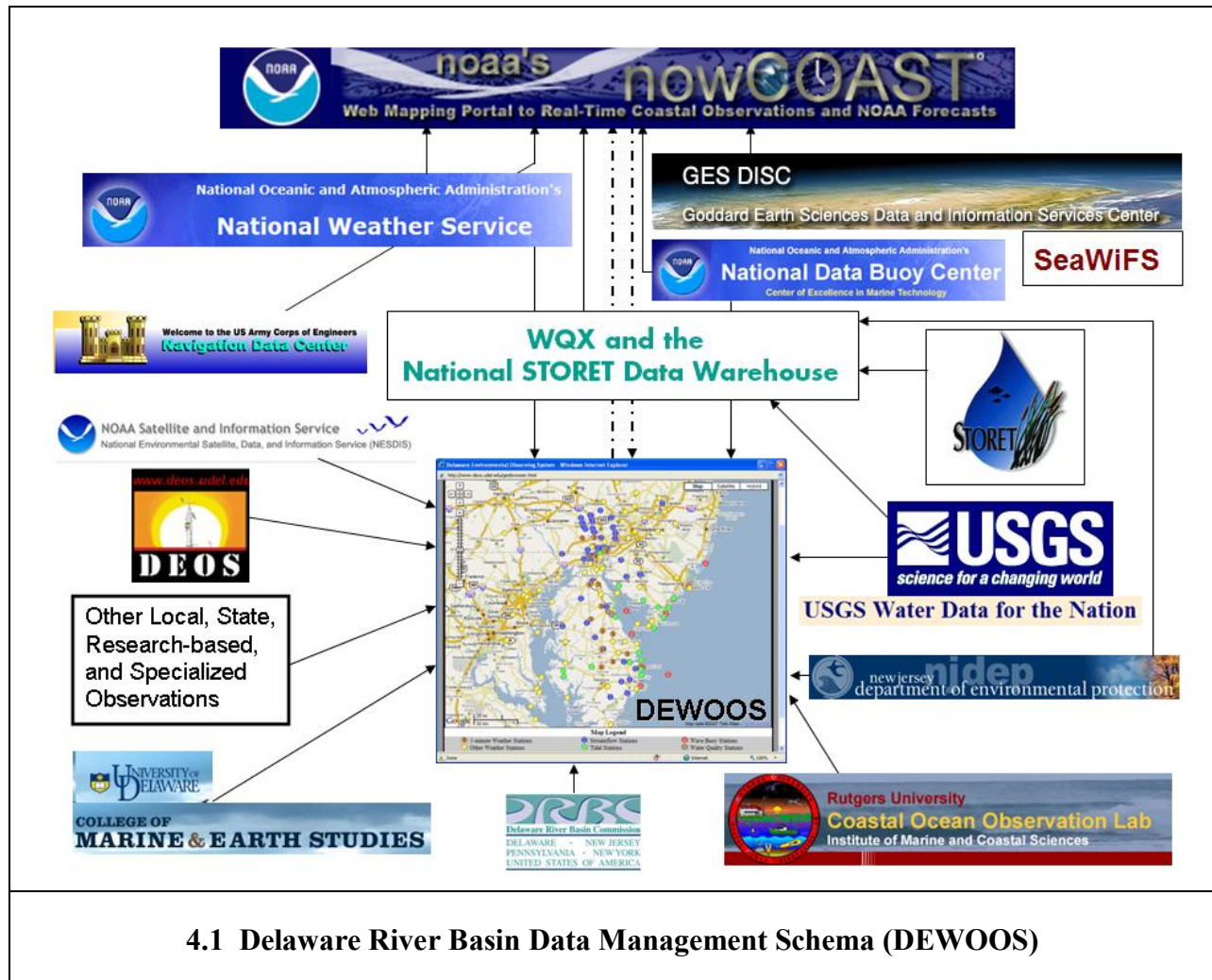
Access Method	Definition	Number of Programs	% of All Programs
Not available	Access is limited to the originator and close collaborators.	3	19%
Hard copy	The data are available in a format not readily usable by a computer.	1	6%
Digital	Data are available in a tab-delimited or regularly-formatted structure, and may be selected for such elements as location and time.	4	25%
Web services	Available for automatic machine-to-machine transfers.	8	50%
Search/Retrieval	Definition		
Hidden	Data can not be found by conventional searches.	3	19%
Portal	The user may discover the existence of a database, but must gain access to the individual database to make further queries.	2	12%
Location - Data Summary	The user may discover sampling sites; only data summaries (e.g., such as “nutrients” or “pesticides,” often with period-of-record information) are available. Data available in the form of a geospatial coverage fits this category.	4	25%
Location - Value	The user may discover sampling sites; result values are available.	7	44%
Metadata level	Definition		
Undocumented	Metadata information is not available.	6	38%
Database	Metadata information is available that pertains to the database as a whole, but individual entries have minimal documentation.	6	38%
ACWI - Partial	Any individual result can be partially documented to ACWI recommendations.	0	0%
ACWI - Full	Any individual result can be fully documented to ACWI recommendations.	4	24%
Archive method	Definition		
At risk	No formal procedures exist for ensuring the data are preserved for future use.	8	50%
Preserved	Data are stored in a secure archive at a single geographic location, therefore prone to catastrophic failure. Retrieval of archived information in the event of catastrophic failure may be problematic.	2	12%

Redundancy

Data are preserved in a failure-resistant system, stored in multiple geographic locations, where they can be dependably retrieved at any time.

6

38%



5. Gap analysis

The National Network was designed to address such management problems as nutrient enrichment, oxygen depletion, and habitat degradation. Table 3-1 in the Network report indicates that a wide array of measurements should be conducted in specific resource compartments: estuaries, near shore coastal waters, offshore coastal waters, rivers, ground water, atmospheric deposition, and wetlands. One of the key design characteristics of the Network is the linkage among various resource components. Table 4 of this report identifies gaps across resource compartments for all major analytes of interest.

Table 4. Draft Gap Analysis Summary Table
W=Water; S=Sediment; N=Nutrients; C=Contaminants; B=Biology; P=Physical Characteristics

	Estuary embayment <i>Condition</i>	Estuary embayment <i>Transport</i>	Estuary embayment <i>Short-term variability</i>	Estuary embayment <i>Other monitoring</i>	Near-shore coast <i>Condition</i>	Near-shore coast <i>Other monitoring</i>	Off-shore coast	Rivers (Monitor at stream gauges at downstream point)	Ground water	Atmospheric Deposition	Wetlands
Network Design	N, P: 50 randomly-selected sites sampled monthly for 1 year out of 5 (W) C: 50 randomly-selected sites sampled 1 year out of 5 (W,S) B: 50 randomly-selected sites sampled 1 year out of 5	N, C, P: 15 sites distributed along salinity gradient sampled monthly every year (W)	P: continuous monitoring (ex: depth of water, salinity, dissolved oxygen, pH, etc.) 2 sites at ends of salinity gradient	Other existing monitoring not specified in Network design and not captured in columns 2-4. For example buoys, shipboard cruises, remote sensing, etc.	N, C, B, P: 50 randomly selected sites per IOOS region, sampled once per year. (See table 3-1 of design report)	Other existing monitoring not specified in Network design and not captured in column 6 using buoys, shipboard cruises, or remote sensing, etc.	IOOS monitoring	N, C: monthly plus high flows (about 15 times per year) B: once per year P: stage and stream flow measured continuously; other characteristics measured monthly plus high flows Design calls for sites located to represent 90% of freshwater outflow from HUC-6 watershed.	Evaluate ground water design. Is ground water significant in the area based on the design document? If important, what kind of data would be required to address ground water in the area? What data gaps exist for the Pilot area?	N,C: 1 wet and 1 dry deposition station monitored weekly per waterbody	N, C, B, P: Network design currently is being refined to include wetlands, no guidance issued yet; entries are based on DEWWG recommendations
Delaware Pilot Design	Delaware Pilot: Participate in National Coastal Assessment Program	Delaware Pilot: 22 fixed location stations regularly sampled 12 times a year from March through October. B: on subset of 8 Stations every sample time. C: on subset of 14 stations every sample time.		Delaware Pilot: See Appendix III.		Delaware Pilot: See Appendix IV.	P: Continuous monitoring of sea surface temperature and surface currents through satellite remote sensing and HF radar. Periodic sub surface temperature, salinity, and currents measured along MARCOOS glider AUV sections. B: Continuous surface CHL-a through remote sensing and periodic sub-surface CHL-a and CDOM measured along MARCOOS gilder AUV sections.	Delaware Pilot: To capture 90% of freshwater flow to estuary, need to capture data at HUC-8 watershed level and five tributary locations as specified in text.	Delaware Pilot: Significant Monitoring Underway (See Text)	N: Phosphorus: 4 sites measuring total P in rain and particles Nitrogen: 7 NTN sites, 2 CASTNET sites C: SOCs: 6 NJADN sites monitoring for PCBs, PAHs, and organochlorine pesticides in gas, aerosol, and precipitation Mercury: 7 MDN sites, 4 MTN sites	

% Complete	N: 80% C: 20% B: 20% P: 80%	N: 60% C: 20% P: 100% B: 50%	P: 50%	N: C: B: P:	N: 0% C: 0% B: 0% P: 0%	N: 0% C: 0% B: 0% P: 25%	N: 0% C: 0% B: 20% P: 80%	N: 10% C: 5% B: 5% P: 100% S: 5%		N: Phosphorus: 0% Nitrogen: 90% C: SOC: 25% Mercury: 75%	N: 0% C: 0% B: 5% P: 10% S: 0%
% No on-going monitoring	N: 0% C: 0% B: 0% P: 0%	N: 0% C: 0% P: 0% B: 0%	P: 50%	N: C: B: P:	N: 100% C: 100% B: 100% P: 100%	N: 40% C: 100% B: 0% P: 50-60%	N: 100% C: 100% B: 80% P: 20%	N: 60% C: 60% B: 60% P: 60%		N: Phosphorus: 100% Nitrogen: 0% C: SOC: 0% Mercury: 0%	N: 100% C: 100% B: 95% P: 90% S: 100%
% Need increased frequency	N: 10% C: 20% B: 20% P: 20%	N: 0% C: 10% P: 0% B: 50%	P:	N: C: B: P:	N: 100% C: 100% B: 100% P: 100%	N: 100% C: 100% B: 50% P: 75%	N: 100% C: 100% B: 100% P: 100%	N: 90% C: 95% B: 95% P: 0% S: 95%		N: Phosphorus: 0% Nitrogen: 0% C: SOC: 0% Mercury: 0%	N: 100% C: 100% B: 95% P: 90% S: 100%
% Need additional analytes or change detection limit	N: 20% C: 80% B: 80% P: 10%	N: 40% C: 80% P: 0%	P:	N: C: B: P:	N: 100% C: 100% B: 100% P: 100%	N: 100% C: 100% B: 100% P: 10%	N: C: B: P:	N: 90% C: 95% B: 95% P: 0%		N: Phosphorus: 100% Nitrogen: 0% C: SOC: 100% Mercury: 0%	N: 100% C: 100% B: 950% P: 90% S: 100%
% Other gaps	N: C: B: P:	N: C: P:	P:	N: C: B: P:	N: 100% C: 100% B: 100% P: 100%	N: C: B: P:	N:100% C: 100% B: 100% P: 100%	N: C: B: P:		N: Phosphorus: 0% Nitrogen: 0% C: SOC: 0% Mercury: 0%	S: 100%
Existing monitoring to address local needs beyond Network Design	N: C: B: P:	N: C: P:	P:	N: C: B: P:	N: C: B: P:	N: C: B: P:	N: C: B: 10% P: 20%	N: C: B: P:		N: Phosphorus: 0% Nitrogen: 100% C: SOC: 100% Mercury: 0%	B: P: C:

Narrative Description of Gap Analysis by Resource Compartment

A short description is provided for each compartment that was well defined in the national network design. *A more detailed description is provided for the Wetlands and Atmospheric Deposition compartments as a proposed Delaware Pilot value added to the next iteration of the national design.*

a. **River Resource Compartment:** Monitoring of Surface-Water Quality Stations above the Head of Tide in the Delaware River Basin Watershed

Extensive monitoring of surface-water discharge and water quality in the 13,539 mi² Delaware River Basin Watershed has been conducted by the DRBC, Federal, State, and local agencies and universities (Figure 1). Over 180 sites in the basin have gaging stations monitoring flow on a real-time basis (<http://waterdata.usgs.gov/nwis/uv?01463500>). Most of these surface-water sites in the basin are monitored for various water-quality constituents at various intervals often using different sampling and analytical methods. Some of the metadata for these monitoring programs are well documented whereas in some instances the metadata are difficult to find online. Additional information on water-quality monitoring in the watershed can be located at the following websites: DRBC (<http://www.state.nj.us/drbc/public.htm>); USGS (<http://nj.usgs.gov/nawqa/delr/>); Delaware DNREC (<http://www.dnrec.state.de.us/water2000/>); New Jersey DEP (<http://www.state.nj.us/dep/dwq/>); Pennsylvania DER (<http://www.depweb.state.pa.us/dep/site/>); and New York (<http://www.dec.state.ny.us>).

The National Monitoring Network (Network) for river sites is designed at a HUC-6 level as sites were selected to monitor 97% of freshwater inflow to Network estuaries and inflow to 70% of Network estuary surface area (<http://acwi.gov/monitoring/network/design/index.html>). The Network for rivers above the head of tide at a HUC-6 level for the Delaware River Basin Watershed (Hydrologic Unit 020401) calls for monitoring only at the Delaware River at Trenton (USGS Station 01463500). This site is located at latitude 40°13'18" and longitude 74°46'41" (NAD83) in Morrisville, PA at river mile 133 from the Atlantic Ocean to the station.

The Network frequency of monitoring for rivers is recommended at monthly plus high flows (about 15 times per year) and once per year for biological characterization and sediment quality (<http://acwi.gov/monitoring/network/design/index.html>). The objectives are to obtain sufficient data to evaluate: the status and trends of water quality constituents at the head of tide; seasonal variability in water quality in relation to flow; and the flux of contaminants from rivers to the estuary or coastal ocean. The major categories of monitoring include physical, chemical (nutrients, metals, and organics), and biological parameters. Most of the inventory at the Delaware River at Trenton summarizes monitoring by USGS and DRBC programs.

Monitoring for recommended physical parameters at the Delaware at Trenton site has been very good for many years and should continue into the future. Discharge has been monitored by the USGS from 1913 to present (Appendix II-1). The mean annual daily flow is 11,820 ft³/s with minimum and maximum annual daily mean flows of 4,708 ft³/s (1965) and 19,810 ft³/s (1928) respectively (<http://nj.usgs.gov/adr/PDF/01463500.2006.pdf>). Physical field characteristics have been monitored intermittently by the USGS since 1944 for temperature, 1962 for dissolved

oxygen, 1963 for specific conductance, 1968 for pH, and from 1949 to 1981 for suspended sediment discharge. The site currently is sampled quarterly for pH, temperature, conductance, dissolved oxygen, and turbidity. The USGS/NJWSC in cooperation with the DRBC operates and maintains real-time-continuous water-quality sensors of temperature, pH, conductance (Appendix II-2), dissolved oxygen, and turbidity since 1968. These water-quality characteristics are continuously monitored and then are transmitted to the GOES satellite and posted on the USGS web and can be retrieved for the previous 31 days (<http://waterdata.usgs.gov/nj/nwis/current/?type=quality>). ***Suspended and bed sediment monitoring data are infrequent and need significant upgrading to meet Network needs.***

Monitoring for recommended nutrient species and related parameters for the Network at the Delaware River at Trenton has been fairly good for the individual species ***but the frequency only occasionally approaches 15 times per year***. Nitrate and other nutrient monitoring began in 1974 (Appendix SW-2A). Combined with discharge measurements, loads can be calculated in relation to discharge (Appendix II-2B). As part of USGS NJ and PA Water Science Center cooperative projects, the Trenton site currently is sampled between 4 to 6 times per year for a broad spectrum of water-quality constituents including major nutrients and contaminants. These data are published in the USGS Annual Report Series—the 2006 water year water-quality Volume 3 is online at <http://nj.usgs.gov/adr/PDF/01463500.2006.pdf>. As part of the USGS National Water Quality Monitoring Assessment, nutrients will be monitored 13 times per year in FY2008 at the Delaware River at Trenton with a recurrence interval of 4 years. Monitoring at a nearby site (two miles downstream) as part of the DRBC Boat Run Monitoring Program is conducted for nutrients 12 times annually.

Monitoring for recommended contaminants (metals and organics) for the Network at the Delaware River at Trenton is fair with respect to the types of contaminants ***but the frequency is less than recommended***. As part of the NAWQA studies, monitoring of water quality in the Delaware River Basin occurred between 1999-2002 (Fischer and others, 2008). During this initial phase, the Delaware River at Trenton site was designated as a fixed integrator site and water was monitored for streamflow, field parameters, major ions, nutrients, mercury organic carbon, suspended sediment, 53 pesticides, and 85 VOCs. Bed sediments were analyzed for 32 organochlorine pesticides, 63 semivolatile organic compounds, 44 trace elements, and mercury. Fish tissues were analyzed for 30 organochlorine pesticides in whole fish and 24 trace elements in fish livers. Total and methylmercury were analyzed in fish fillets, bed sediment, and water. In FY2008 as part of the Delaware River Basin NAWQA study, the Trenton site is scheduled to be sampled 15 times per year for selected anions, nutrients and suspended sediments 16 times per year and selected pesticides 13 times per year (J. Fischer, USGS, written commun. 2007). This sampling scheme is to be recurring every four years.

Because the Delaware Estuary and tidal portions of the river are over 133 miles long, four sites on the tidal parts of the Delaware River downstream of the Trenton gage are monitored continuously by the USGS and several times per year for discrete samples including sites at the Ben Franklin Bridge, Chester, and Reedy Island on the Pennsylvania side of the Delaware River. At these sites, conductivity is measured to determine the advance of the salt-water wedge up the tidal part of the river during lower flows to protect public supply surface-water intakes in Pennsylvania and New Jersey (Appendix II-3).

Several moderate sized tributaries discharge to the Delaware River south of the Delaware gage (Appendix II-4). The most notable of these tributaries for discharge and contaminant loads are the Schuylkill River just south of Philadelphia, PA, the Maurice River in Cumberland County New Jersey, and Christina River in Delaware. Monitoring programs at these sites are conducted by various Federal, State, and local agencies and universities. The USGS monitors at all three sites. ***It is a recommendation of the Pilot Study Steering Committee that each of these sites be included in the Network to monitor for flows and contaminant loads into the estuary downstream of the head of tide at Trenton.***

Fischer, J.M, Riva-Murray, K., Hickman, R.E., Chichester, D.C., Brightbill, R.A., Romanok, K.R., and Bilger, M.D, Water Quality in the Delaware River Basin Pennsylvania, New Jersey, New York, and Delaware, 1998-2001: U.S. Geological Survey Circular 1227, 38 p.

b. Estuary Embayment Resource Compartment

The full tidal length of the Delaware Estuary is monitored regularly through the Delaware River Basin Commission (DRBC) Boat-Run program which has been operated continuously, since 1967. The boat-run monitoring is conducted with consistent discrete sampling and analyses along a transect of the estuary, covering the entire tidal freshwater river to the mouth of the bay; it has been subjected to strict US EPA QA/QC criteria and has been regularly entered into the EPA STORET system.

As noted above, the USGS has maintained a tide gauge at the head of the tide of the Delaware River at Trenton, NJ since 1913 (responsible for 58% of the total water input to the Delaware Estuary); the gauging station is on the Schuylkill River at Philadelphia (since 1931), captures another 14% of the total input (Smullen et al, 1983). In addition to water input the gauging stations have measurements of other parameters. USGS also maintains several other continual measurements sites along the tidal river and into the upper region of the salinity gradient of the bay.

A long term biogeochemical research effort conducted at the University of Delaware, which has been integrated with the DRBC monitoring, was started in 1978 and continues. This research effort has allowed a good characterization of the Delaware Estuary biogeochemical response to water quality.

The DRBC boat run, USGS gauging stations, and University of Delaware research programs together have provided valuable information on water quality management, especially in the tidal river region. Continuation of these discrete sampling programs will assist in guiding management in the future; however, for more comprehensive management for the entire estuary, additional real-time continuous measurements are also needed. Additional parameters should be measured at the major gauging stations and at USGS sites within the estuary. In the lower part of the estuary, most of the Delaware Bay, there are some beginnings of real time measurements including sites maintained by Delaware Department of Natural Resources and Environmental Control (DNREC), New Jersey Department of Environmental Protection (DEP), NOAA PORTS program and some limited time deployment observing platforms from the University of Delaware. Improvements and additions to these ongoing observing capabilities and new

additions are being planned. While some of the ongoing real-time observation systems were designed for navigation, safety, and emergency management, many of the measurements for these purposes and for water quality are overlapping and compatible.

c. Near-shore Coast Resource Compartment:

The near-shore ocean waters of the Delaware Pilot for the NMN consist of the Atlantic Ocean from the Rutgers University Endurance Line off of Little Egg Inlet, south to the Delaware/Maryland state line and out in the ocean to 12 nautical miles. Within this region, USEPA, NJDEP and Rutgers University conducted a probabilistic monitoring effort of benthic community in 2007 as a research pilot for a possible future routine monitoring effort, but at this time there currently is no routine, probabilistic monitoring. The cost of establishing probabilistic monitoring comparable to National Coastal Assessment would be \$4,000/sampling location/year. There is, however, considerable non-probabilistic monitoring including remote sensing (both satellite and aircraft), automated monitoring (autonomous underwater vehicles) and vessel-based monitoring. Much of this is covered under the Mid-Atlantic Regional Coastal Ocean Observation System (MARCOOS).

It is difficult to assign the appropriate frequency for routine monitoring for the nutrients parameters. Since nutrient monitoring is performed to provide data on the factors driving algal blooms and low DO, the frequency of nutrient monitoring will be driven by the temporal variability of these response factors. Monthly or quarterly routine sampling may not be sufficient to characterize responses that occur on the order of days. ***Since the nutrients are being monitored as a driving factor for phytoplankton blooms (and resulting low DO levels), it is suggested that routine remote sensing (satellite and/or aircraft) be used to identify episodic phytoplankton blooms and upwelling conditions that may relate to elevated nutrient conditions. Sampling for nutrients should be targeted to those times and locations where knowledge of nutrient levels is most critical.***

It is suggested that colored dissolved organic matter (CDOM) can serve as a surrogate for salinity. It is best measured by vessel sampling with lab analysis, however it can also be measured fluorometrically using gliders. There is also ongoing research to measure it using remote sensing.

d. Off-shore Coast Resource Compartment:

The offshore extent of the region is monitored in large part by the Mid-Atlantic Regional Coastal Ocean Observation Lab (MARCOOS). MARCOOS is a regional observatory funded through the NOAA Integrated Ocean Observing System (IOOS) program. MARCOOS as it exists today is focused on delivery physical and biological observations and forecasts throughout the Mid-Atlantic Bight. It brings three key technologies that allow for fine scale characterization of the coastal ocean including the acquisition of data streams from U.S. and foreign satellites in space, a network of high-frequency radars deployed along the shore, and a fleet of robotic gliders flying beneath the ocean surface. These observations are linked to four forecast modeling systems to deliver targeted products to end-users throughout the region. The remote sensing data provides a broad spatial coverage focused on the ocean surface. The variable measurements are primarily collected on regular glider AUV missions that transect the MAB. These gliders are all equipped with CTD measuring ocean temperature and salinity throughout the water column. Some vehicles are also equipped with optical sensor that measure backscatter and Chl-a fluorescence. These observations complement the existing NOAA NDBC backbone providing real-time monitoring of physical parameters.

e. Ground Water Quality Monitoring Resource Compartment

Extensive monitoring of ground-water levels and ground-water quality in the 13,539 mi² Delaware River Basin Watershed has been conducted by Federal, State, and local agencies. The Federal Clean Water Act Amendments of 1977 require that States monitor and report on the quality of ground water and surface water. Each State coordinates their ground-water quality monitoring network. Over 5,000 wells have been sampled in Delaware River Basin for water quality. Most of these ground-water sites in the basin are monitored for various water-quality constituents at various intervals often using different sampling and analytical methods. Some of the metadata for these monitoring programs are well documented whereas in some instances the metadata are difficult to find online. Additional information on ground-water-quality monitoring in the watershed can be located at the following websites: USGS (<http://nj.usgs.gov/nawqa/delr/>); Delaware DNREC (<http://www.dnrec.state.de.us/water2000/>); New Jersey DEP (<http://www.state.nj.us/dep/dwq/>); Pennsylvania DER (<http://www.depweb.state.pa.us/dep/site/>); and New York (<http://www.dec.state.ny.us>).

Guidance for ground-water-quality monitoring for the National Monitoring Network is still being developed. Except for nutrients, no recommendations were made for constituents and minimum reporting levels for ground water. Dissolved nitrate plus nitrite is the only Tier 1 analyte recommended for analysis. Dissolved ammonium and dissolved orthophosphate are recommended as Tier 2 analytes and dissolved organic carbon as an ancillary analyte.

In New Jersey, the Ambient Ground Water Quality Monitoring Network (AGWQMN) is a NJDEP/USGS cooperative project (<http://www.nj.gov/dep/njgs/geodata/dgs05-2.htm>). The original (pre-1999) network mainly focused on determining ground-water quality as a function of geology throughout New Jersey using public, private, irrigation, observation and other types of existing wells. The goals of the recently completed redesigned network are to determine the status and trends of shallow ground-water quality as a function of land use related non-point

source pollution in New Jersey. Most of the shallow wells used were installed by the NJGS or their contractors to meet the goals of the redesigned network. This network consists of 150 wells screened at the water table that are sampled 30 per year, on a 5-year cycle (Appendix IV-1). The first cycle was completed and the second started in 2004. The New Jersey Geological Survey (NJGS) manages the network design, well installation, well maintenance and data interpretation and reporting. The NJDEP Bureau of Fresh Water and Biological Monitoring and the United States Geological Survey (USGS) collect the well-water samples, and the USGS laboratory in Denver, Colorado analyzes them. Chemical and physical parameters analyzed at each well include: field parameters such as pH, specific conductance, dissolved oxygen, water temperature and alkalinity; major ions, trace elements (metals), gross-alpha particle activity (radionuclides), volatile organic compounds, nutrients, and pesticides. The metadata for this monitoring network is well documented (Appendix IV-2).

In Pennsylvania, ground-water quality has been monitored by eight agencies in over 8,000 wells (Appendix IV-3) with the greatest concentration of wells in southeastern Pennsylvania in the Delaware River Basin Watershed. The metadata for these monitoring wells are well documented (<http://pubs.usgs.gov/ds/ds150/pdf/ds-150.pdf>). The ground-water-quality data from the different source agencies varied in type and number of analyses; however, the analyses are represented by 12 major analyte groups: biological (bacteria and viruses), fungicides, herbicides, insecticides, major ions, minor ions (including trace elements), nutrients (dominantly nitrate and nitrite as nitrogen), pesticides, radiochemicals (dominantly radon or radium), volatile organic compounds, wastewater compounds, and water characteristics (dominantly field pH, field specific conductance, and hardness). An example of the database of nitrate concentrations in ground water in Watershed 20 are in Appendix IV-4.

In Delaware, the Delaware Department of Natural Resources and Environmental Control has been implementing a different type of approach to assess, manage, and protect Delaware's natural resources. This approach, known as Whole Basin Management, encourages the various programs from throughout the Department to work in an integrated manner to assess different geographic areas of the state defined on the basis of drainage patterns (<http://www.dnrec.delaware.gov/wholebasin>). In Appendix IV-5 the locations of wells sampled for nitrate in the Delaware River Basin Watershed as part of the Whole Basin Management are shown.

In New York, the U.S. Geological Survey and New York State Department of Environmental Conservation have developed a program in which ground-water quality is assessed in 2 to 3 of New York State's 14 major basins each year. To characterize the quality of ground water in the Delaware River Basin in New York, water samples were collected from December 2005 to February 2006 from 10 wells finished in bedrock (Appendix IV-6). Data from 9 samples collected from wells finished in sand and gravel in July and August 2001 for the National Water Quality Assessment Program also are included. Ground-water samples were collected and processed using standard U.S. Geological Survey procedures. Samples were analyzed for more than 230 properties and compounds, including physical properties, major ions, nutrients, trace elements, radon-222, pesticides and pesticide degradates, volatile organic compounds, and bacteria (<http://pubs.usgs.gov/of/2007/1098/>)

f. Wetlands Resource Compartment

To date, no single entity has been charged with tracking both the extent and condition of tidal wetlands across the Delaware Estuary. Monitoring wetland condition is just as important as monitoring extent because reduced health is usually a precursor of acreage loss, often occurring en masse during punctuated disturbance events such as storms. Therefore, restoration and protection efforts should carefully weigh the net benefits of maintaining marsh condition as well as acreage. Monitoring data is essential to inform such decision-making. A Delaware Estuary Wetland Workgroup (DEWWG) was formed in 2007 to prepare a monitoring and assessment design for tidal wetlands as part of this report. This workgroup includes state and federal representatives from DE, NJ, PA, EPA, as well as academics from universities and non-profits. Working with the latest national guidance from EPA (<http://www.epa.gov/owow/wetlands/monitor/>) and in concert with the Mid-Atlantic Wetland Workgroup (http://www.mawwg.psu.edu/overview/meetings_held.asp), the DEWWG developed a three-tiered design that would determine: 1) the extent and condition of tidal wetlands in the Delaware Estuary, 2) how tidal wetlands are changing over time in response to major physical, chemical and biological stressors and anthropogenic alterations in the watershed such as sea level rise, shoreline modification, channel deepening, nutrient balance, and invasive species, and 3) how changes in wetland condition affect the ecosystem services that they provide. By meeting these objectives, the wetland monitoring program would help address key management areas, such as: 1) prioritizing wetland restoration and protection activities, 2) improving regulatory decisions, and 3) assessing ecological services furnished by marshes in different areas and states of functionality.

The Delaware Pilot hopes to be a value added to the national design by thinking through a monitoring framework that speaks to both wetland extent and condition as follows:

Description of the Proposed Tidal Wetland Monitoring Program. The Delaware Estuary Wetland Monitoring and Assessment Program (DEWMAP) would be structured using terminology supplied in the EPA guidance, and summarized as follows:

- Sample Frame: all tidal wetlands in the Delaware Estuary watershed.
- Subpopulations: wetland type (oligohaline, mesohaline, polyhaline); state (DE, NJ, PA)

Assessment sites will be allocated to each subpopulation to allow the reporting of condition or other measures for each subpopulation independently in addition to the overall reporting for the entire Delaware Estuary Watershed.

The design itself is summarized as follows:

- Tier I - A landscape assessment based on remote sensing techniques to evaluate the general condition of all tidal wetlands. Indicators that can be gathered with remote sensing imagery including surrounding land use and wetland vegetation characteristics will be used (e.g. Kearney et al. (2002).
- Tier II - A probabilistic “rapid” sampling to determine the condition of wetlands in the watershed stratified by wetland type and state. Sites will be randomly located and assessed with numerous field measurements.
- Tier III - Fixed monitoring stations in tidal wetlands that assess changes associated with major stressors and shifts in base forcing functions in the estuary (e.g., sea level rise, sediment budgets, temperature). These stations will be located in each subpopulation and sampled with intensive measurements of tidal wetland function and condition.

Assessment metrics for each tier will follow national guidance to develop “core” indicators that facilitate comparisons among the subpopulations within the Delaware Estuary, as well as for comparisons to other wetland ecosystems nationally. Following EPA guidance, the design will also allow for “supplemental” indicators to be developed that specifically target regional processes and issues of heightened interest (e.g. subsidence interactions). Table 5 lists leading indicators selected by the DEWWG as relevant for DEWMAP. This list is preliminary and it is expected to be further refined as additional national guidance is obtained and with enhanced regional participation in DEWWG once funding becomes available.

Table 5. Example indicators and metrics for a 3-tiered Delaware Estuary wetland monitoring program.

Design Component	Example Indicators	Example Metrics
Tier 1	Wetland Extent Wetland Buffer Condition Wetland Contiguousness Historic Change Wetland Morphology Plant Community Integrity Shoreline Condition Anthropogenic Alterations	wetland acreage (hectares) per subpopulation and NWI attribute type adjacent land use (e.g., % natural vs. developed in 100m band) connectivity (inter/intra); patch sizes and fragmentation loss or gain in acreage for different subpopulations & attributes percent open water; edge to area ratios vegetation community/type (e.g., <i>Phragmites</i> vs. <i>Spartina</i> , high marsh vs. low marsh, bare soil, open water) edge status (e.g., hardening, erosion) channel straightening, ditching, tide gates, groundwater withdrawals
Tier 2	Plant Community Integrity Primary Production Wetland Morphology Invertebrate Community Integrity (sessile species) Wildlife Habitat Integrity (mobile species) Hydrological and Shoreline Integrity Substrate Integrity Elevation and Sediment Budget	vegetation community type (description of species assemblage) invasive species (percent cover of <i>Phragmites</i>) species list (floristic quality assessment index) vegetation structure board below and above ground biomass percent open water; edge to area ratios presence and relative abundance of functional dominant and bioindicator species evidence of fish and mobile shellfish; avian IBI evidence of hydrological alterations or impairment (e.g. depressions, dikes, rip rap) percent organic matter and sediment description relative elevation, evidence of accretion or subsidence, wrack accumulation
Tier 3	Water Quality Biogeochemical Cycling Carbon Storage Elevation and Sediment Budget Plant Community Integrity Functional Dominant Fauna Integrity	fixed monitoring stations in second order tidal creek (temperature, specific conductivity, pH, turbidity, DO, water level) grab samples in tidal creek for dissolved nutrients and seston quantity & quality, ebb & flood tides (TSS, chlorophyll, proximate biochemistry and stoichiometry) sediment porewater nutrient concentrations, forms, stoichiometric ratios; denitrification rates carbon sequestration in belowground biomass; litter accumulation Sediment Elevation Table (SET), elevation relative to sea level (in addition to Tier 2 metrics) vegetation robustness (percent cover and stem counts per species) (in addition to Tier 2 metrics) invertebrate and vertebrate species lists along intertidal edge and high marsh, biofiltration capacity of bivalves

Wetlands Implementation Strategy and Summary of Costs

Tier 1 would be undertaken as a comprehensive census using primarily remote sensing technology, which would be repeated every five years (projected Tier 1 cost: \$180,000 every five years). Tier 2 would also be undertaken every five years, with the entire study region being assessed in the same year. For the probabilistic design in Tier 2, a minimum of 50 sites will be sampled per subpopulation, and 300 overall. Three field crews will be needed for a 3 month summer survey, each crew having three trained staff responsible for surveying 100 sites (average two sites/day) with the rapid assessment approach (projected Tier 2 cost: \$225,000 every five years).

Tier 3 would consist of the deployment and maintenance of fixed monitoring stations, which would require an initial investment and then an annual maintenance cost. Fixed stations would be established at 5 sites, representing all subpopulations. Each station will consist of a fixed platform with data sondes that is situated in a second or third order tidal creek within a larger tract of tidal marsh. Water monitoring instrumentation will be affixed as per standard methods developed at the St. Jones National Estuarine Research Reserve in DE. The monitoring station will collect data every 15 minutes with YSI 6600 sondes, measuring temperature, specific conductivity, pH, turbidity, DO and water level. Additional water quality metrics will be collected with grab samples beginning in Year 2 and approximately monthly on both ebb and flood tides for analysis of dissolved nutrients and seston quantity and quality (TSS, chlorophyll, proximate biochemistry and stoichiometry). Additionally, transects for repeated analyses of marsh condition will be extended landward from the monitoring platform using temporary boardwalks situated from the littoral edge through the high marsh plain. Sediment elevation tables (SET) will be deployed at each site. After set up of the monitoring stations, biological and biogeochemical metrics will be assessed seasonally along transects (as per Table 5).

The requested budget for Tier 3 is summarized in Table 6. In Year 1, \$90,000 is requested to purchase, install and calibrate instrumentation as well as perform baseline sampling at the selected sites. In Year 2, \$95,000 is requested to maintain instrumentation and initiate detailed monthly and seasonal analyses of marsh condition. In Year 3, \$105,000 is requested to complete the detailed on-the-ground assessments as well as to continue maintenance of the instrumentation.

Table 6. Detailed Cost Description for Tier 3.

Year	Activities	Costs	PA (n=1)	DE (n=2)	NJ (n=2)	Regional	Total
1	Planning, purchasing, final site selection, ground-truthing	probe and SET	\$11,000	\$22,000	\$22,000	-	\$55,000
		staff time to install and calibrate	\$4,000	\$8,000	\$8,000	\$5,000	\$25,000
		coordination and baseline field/lab work	-	-	-	\$20,000	\$20,000
2	Instrument calibration, maintenance and finish baseline	calibrate and maintain probes	\$3,000	\$6,000	\$6,000	-	\$15,000
		Field staffing	-	-	-	\$55,000	\$55,000
		coordination and lab work	-	-	-	\$25,000	\$25,000
3	probe maintenance, seasonal analyses, writeups	calibrate and maintain probes	\$3,250	\$6,500	\$6,500	-	\$16,250
		Field staffing	-	-	-	\$60,000	\$60,000
		Coordination, lab work, report	-	-	-	\$35,000	\$35,000
4	repeat year 3	repeat year 3	\$3,250	\$6,500	\$6,500	\$95,000	111,250
5	repeat year 3	repeat year 3	\$3,250	\$6,500	\$6,500	\$95,000	111,250
Total	-	-	-	-	-	-	\$528,750

The requested budget for all three tiers of the program is summarized in Table 7, which would ideally be repeated every 5 years. The budget for Tiers 1 and 2 is structured to account for design work, training and purchasing in Year 1, the bulk of the field work in Year 2, and final sample and data analysis and reporting in Year 3, followed by a two year period until the effort would be repeated.

Table 7. Summary of Costs per Five Years for the Delaware Estuary Wetland Monitoring and Assessment Program.

Tier	Year 1	Year 2	Year 3	Year 4	Year 5	Total
1	\$25,000	\$125,000	\$30,000	-	-	\$180,000
2	\$25,000	\$140,000	\$60,000	-	-	\$225,000
3	\$100,000	\$95,000	111,250	\$111,250	\$111,250	\$528,750
Total	\$150,000	\$360,000	\$201,250	\$111,250	\$111,250	\$933,750

g. Atmospheric Deposition Resource Compartment

Charge to Atmospheric Deposition Refinement Workgroup:

1. Develop an approach for monitoring the flux of constituents contributed to the Delaware River Basin and adjacent coastal waters by atmospheric deposition. The design should address wet, dry particle, and gaseous deposition and allow for assessment of current fluxes and establish a basis for determining trends over time.
2. The design should assure providing guidance on minimum spatial density and sampling frequency.
3. Consistent with the rest of the Network design, both probabilistic and targeted designs are appropriate. Modeling may also be appropriate as a way to extend information derived from observations to a wider area.
4. Develop guidelines for assessing data comparability between monitoring programs.

5. Make a recommendation as to the extent to which the National Atmospheric Deposition Program can accommodate the regional needs of the Delaware River, and recommend how regional monitoring programs can coordinate with the NADP.

Tasks 1 and 2.

The workgroup examined tasks 1 and 2 in the context of the relevant analyte classes, which are: major ions, nutrients, mercury, and semivolatile organic compounds (SOCs). Major ions consist of calcium, magnesium, potassium, sodium, chloride, and sulfate. Nutrients consist of nitrate, nitrite, ammonium, organic nitrogen, phosphorus, and silica. SOCs include pesticides (aldrin, dieldrin, DDT, DDD, DDE, chlordane, hexachlorobenzene, mirex), polychlorinated biphenyls (PCBs), dioxins, furans, and PAHs (such as naphthalene, phenanthrene, pyrene, and benzo(a)pyrene). A summary of current and recommended wet and dry deposition monitoring in the Delaware River Basin (DRB) is shown in Table 6.

Before discussing each analyte class, it is important to make a few general observations. **First, atmospheric deposition loads to the Delaware River Basin are likely to be dominated by deposition to the Delaware Bay due to its large surface area relative to watershed area. Thus, all analyte classes should include at least one monitoring site designed to measure the atmospheric flux directly to the surface of the Bay.** The National Atmospheric Deposition Working Group has suggested that monitoring sites for atmospheric deposition should be established at sites directly over water. We suggest that one of the NOAA PORTS (Physical Oceanographic Real-Time System) sites in Delaware Bay, such as Brown Shoal Light or Brandywine Shoal, would be good locations for an over-water atmospheric deposition monitoring station.

Second, many contaminants (nitrogen species, SOCs) display strong local gradients which may be related to urbanization, agriculture, and/or other land-use issues. Therefore monitoring networks should include sites in a variety of land-use classes. Ideally, many (10 or more) sites would be operated throughout the DRB for each contaminant, but this is probably not financially possible. **At a minimum, monitoring networks for most species should include both urban and rural sites.**

Third, atmospheric deposition can occur via three possible mechanisms: wet deposition via precipitation, dry particle deposition, and gaseous deposition (exchange). All three modes can operate at the water surface (direct deposition) or can involve deposition to land surfaces. Contaminants deposited to land can then sometimes be re-mobilized to enter water bodies (indirect atmospheric deposition). Gaseous deposition obviously only operates for contaminants that have significant gas-phase concentrations, such as SOCs, mercury, and ammonia. Many other species (i.e. phosphorus) do not exist in the gas phase, so that only dry particle and wet deposition are important. In some cases, dry particle and gaseous deposition have received less attention than wet deposition, probably because wet deposition is easier to measure. In the recommendations that follow, **we have attempted to point out circumstances in which dry particle and gaseous deposition require more attention.**

Fourth, the monitoring should be conducted over the long term so that temporal trends in contaminant concentrations can be detected. Information about these temporal trends is vitally important in modeling the response of the water column to changes over time.

Major ions

The current monitoring of wet deposition of major ions in the Delaware Basin includes 7 NADP/NTN sites as well as 1 PADEP acid rain monitoring sites (Table 6). All 8 of these sites focus on wet deposition and are either rural or suburban. The committee recommends that at least one urban site be established in Philadelphia, co-located with one of the sites run by the city of Philadelphia (Appendix I). More than one site would be desirable but may not be financially feasible. The NADP/AIRMON site at Lewes, DE partially captures the signal of deposition of major ions to Delaware Bay, but major ions should also be monitored over water. The weekly sampling frequency for both the NADP/NTN and PADEP sites is thought to be adequate. Dry deposition should receive more attention. This is dealt with more explicitly under nutrients, below.

Nutrients

Atmospheric deposition of phosphorus is not well monitored in the DRB. A single site monitors ortho phosphate in precipitation (the NADP AIRMON site at Lewes, DE). This site is in a good location to capture the signal of P deposition to Delaware Bay, but measurement of ortho phosphate is probably inadequate. Instead, total P should be measured in both precipitation and the particle phase. Since this has not traditionally been done within the various NADP networks, a pilot study should be conducted to develop appropriate methodology. Once the methods are finalized, we recommend that total P in precipitation and particle be measured at four sites: the existing AIRMON site at Lewes, DE, as well as Milford, PA, Washington Crossing, NJ, and an over-water site in Delaware Bay. This would provide coverage at the upper, middle, and lower stretches of the River, as well as Delaware Bay. P in the atmosphere is not thought to be related to urbanization, so an urban site measuring total P in precipitation and particles is probably not necessary.

Within the context of atmospheric deposition of nitrogen, nitrate and ammonium are important and relatively well monitored, but organic nitrogen may also be important and is not monitored in any systematic way. NADP has recently begun a program to measure ammonia with passive samplers which will provide relatively dense spatial coverage and therefore characterize the urban and agricultural ammonia signal. Current monitoring for nitrate and ammonium in the DRB consists of the 7 NADP/NTN sites (wet only) and the one PADEP acid rain sites (wet only). The Washington Crossing NADP/NTN site is also a CASTNET site where both wet and dry deposition of nitrate, ammonium, and sulfur oxides are measured. None of these sites represent the urban signal. At least one urban CASTNET site should be established in Philadelphia to measure both wet and dry nutrient deposition. Also, current monitoring is heavily focused on wet deposition. At least one additional CASTNET site should be established to expand our understanding of dry deposition of nutrients, focusing on the Delaware Bay at either Lewes, DE, or an over-water site (Table 6). Establishment of a monitoring framework for organic nitrogen is not possible at this time because the methods are not yet well established. However, a pilot study that includes both an urban and a rural site should be conducted to determine whether atmospheric deposition of organic nitrogen is significant in the DRB.

Mercury

Current monitoring for total mercury in precipitation in the DRB is performed at 5 NADP/MDN sites, 2 of which are part of the PADEP monitoring program (Table 6). Sampling frequency (weekly) is adequate. Sampling at the PADEP sites is performed via MDN protocols, and samples are sent to the same contract lab used by the MDN network.

NJDEP conducts speciated mercury monitoring at New Brunswick, Chester, and Elizabeth, NJ, and intends to find a new location in Camden to re-start monitoring there. They use a TEKRAN instrument to measure reactive gaseous mercury, particle-bound mercury and elemental mercury. This approach is similar to that proposed by NADPs Atmospheric Initiative, which is currently being established within the NADP framework to examine mercury speciation (reactive gaseous mercury, particulate bound mercury and elemental mercury) and to examine wet, dry and total atmospheric deposition of mercury.

Three deficiencies are noted within the mercury monitoring program. First, urban influences are not measured by the MDN due to the location of the sites. Second, a site is needed to measure mercury deposition to Delaware Bay. Thus we recommend that two MDN sites be added, one at Lewes, DE or at an over-water site and another co-located with NJDEP's new speciated mercury site in Camden. Third, most of the current mercury monitoring focuses on total mercury in rain. We recommend that at least one urban site be established to measure speciated mercury, probably the relocation of the NJDEP site in Camden. NJDEP should continue their speciated mercury monitoring, and their sites should eventually be incorporated into the MTN.

SOCs

Organic pollutants are thought to be the single most important issue facing the Delaware River. PCBs are a specific concern, resulting in the establishment of a TMDL for PCBs in the tidal Delaware promulgated in 2003. In support of the TMDL effort, the existing New Jersey Atmospheric Deposition Network (NJADN) was expanded by the DRBC to include new sites in Pennsylvania and Delaware in order to assess atmospheric deposition of PCBs to the river (Table 6). At one time the NJADN included 8 sites relevant to the DRB and coastal Atlantic. Presently DRBC supports three of the sites operating at New Brunswick, NJ; Camden, NJ; and Lums Pond, DE. DNREC also operates 5 sites in Delaware at which PAHs and polychlorinated dioxins and furans are measured.

Monitoring for atmospheric deposition of SOC is different in many important respects from sampling for major ions, nutrients, and mercury. First, no national standard sampling protocols are available, and no national network exists. Second, analysis for SOC is typically much more expensive and relies on high-resolution GCMS analysis, which is beyond the means of most university laboratories. Due to the high cost of these analyses and the lack of a national effort in this area, monitoring networks for atmospheric deposition of SOC have typically been run as research efforts by universities using non-standardized methods. Each sample (gas, particle, or precipitation) can be analyzed for a wide range of SOC, including PCBs, chlorinated pesticides, and PAHs, as well as some emerging contaminants such as brominated flame retardants. With slight modifications (primarily longer collection times), these samples can also be used to measure polychlorinated dioxins and furans.

There are several deficiencies noted in the SOC monitoring efforts in the DRB. First, additional monitoring sites are needed, in particular, sites which represent the northern and southern stretches of the river (possibly at Washington Crossing and Cape May Courthouse). Alternatively, SOC sampling could be added to the Lewes, DE site or an over-water site. Second, a national SOC monitoring framework (primarily emphasizing the QA aspects of sampling and analysis) should be developed and disseminated to the states, possibly by the NADP. This framework should identify lower cost analysis methods than the high resolution GCMS methods approved by EPA. This framework should be viewed as the first step in establishing a national SOC monitoring network, which should build on the existing IADN and

NJADN networks. Development of this framework will involve an extensive data comparability study across universities and networks, as well as extensive method development.

Task 3.

The monitoring framework suggested under Tasks 1 and 2 is designed to provide adequate spatial and temporal coverage of the DRB in order to characterize urban vs. rural concentration gradients and to identify long-term time trends. This design provides the minimum reasonable coverage in order to keep continuous operating costs under control. Two important questions cannot be addressed within the framework suggested above: (1) What are the spatial variations in contaminant concentrations on the scale of 10's of km? (2) How can the measured concentrations be accurately converted to atmospheric deposition loads, either directly to the water surface of the River/Estuary or indirectly to the watershed? To answer these questions, additional types of research are needed.

The suggested monitoring framework developed under Tasks 1 and 2 attempts to characterize the most obvious spatial variations in contaminant concentrations by placing monitoring sites in both urban and rural areas, since many contaminants (SOCs, nitrogen species) display urban gradients. However, interpolation between sites will be necessary when assigning atmospheric deposition fluxes and loads to the DRB. This is especially problematic when large gradients exist. The committee therefore recommends that in addition to the monitoring framework described above, targeted short term intensive sampling be conducted in order to assess spatial variations in contaminant concentrations and to identify local sources. In many cases, this intensive sampling can be conducted using passive samplers. This has been done in the DRB for SOCs and can be done for ammonia via the project currently in development by NADP.

Converting measured concentrations into loads is not trivial. Most atmospheric deposition studies to date have focused on wet deposition by measuring the concentration of each contaminant in precipitation samples and then multiplying these values by the precipitation depth to calculate wet deposition flux. Because precipitation depth (which corresponds to the deposition velocity) is easy to measure, it is easy to calculate an accurate flux at the point of measurement, and to use meteorological data and models to predict precipitation depths at other locations. In contrast, dry particle and gaseous deposition, which are important for nutrients, mercury, and SOCs, have largely been ignored, except in the case of SOCs. Dry particle and gaseous deposition are addressed by measuring contaminant concentrations in the particle and gas phases in addition to precipitation. These concentrations must then be converted to deposition fluxes via application of an appropriate deposition velocity. Unfortunately, dry particle and gaseous deposition velocities are highly uncertain and difficult to measure. Many numbers exist in the literature, but they often vary by an order of magnitude or more. We therefore recommend that monitoring for atmospheric deposition should continue to focus on the measurement of concentrations, but that a comprehensive study of dry deposition velocities for particle-bound (mercury, nutrients, SOCs) and gaseous (mercury, SOCs) species be conducted. This study should involve at least two study locations: one urban and one rural.

Task 4.

Data comparability is an issue for all analyte classes. For major ions and nutrients, data comparability between the PADEP and NADP sites should be assessed. For mercury, data comparability between the MDN sites and other mercury monitoring networks is being investigated. The new TEKRAN mercury data collected via the NADP's Atmospheric Initiative should also be compared to that collected by the NJDEP speciated mercury sampling program.

Finally, data comparability for SOC sampling is particularly problematic. As noted above, there is no national network and no consistent set of sampling and analysis guidelines for SOC sampling. NADP or another national body should first conduct a pilot study of the QA/QC aspects of atmospheric SOC measurements and then disseminate a guidance document on best practices in SOC measurements to states and local agencies. Building on this effort, a national SOC monitoring network should be established, building on the existing IADN and NJADN networks.

Data comparability studies should investigate all aspects of the measurements, including:

- Sample collection including sampling equipment (esp. rain gage)
- Sample storage, transport, and holding times
- Standardized analytical methodologies
- Interlaboratory comparisons among laboratories using a common set of analytical methodologies
- Laboratory auditing/certification
- Data reduction (Data screening, data completeness criteria, data management, blank correction, etc.)
- Training of personnel

Task 5.

The primary role of NADP is in ensuring comparability of data across monitoring sites that are administered and paid for by a variety of state and local agencies. In this capacity, NADP is invaluable, and all new monitoring should be conducted within the NADP umbrella if possible. A stable, consistent level of funding must be provided by a national agency such as EPA to ensure that monitoring occurs routinely and without interruption. SOCs are a special case, since the NADP currently has no monitoring program for these analytes. We suggest that the NADP establish an advisory board to aid in the development of QA/QC protocols for SOC sampling.

Table 8. Relevant air monitoring sites and parameters measured.

Site	Site type	Agency or program	Current analytes	Recommended additions
Milford, PA	Rural	NADP NTN MDN	Precip: Ca Mg K Na NH ₄ NO ₃ Cl SO ₄ H pH conductivity Total Hg	Add total P in precip
Washington Crossing, NJ	Suburban/ rural	NADP NTN	Precip: Ca Mg K Na NH ₄ NO ₃ Cl SO ₄ H pH conductivity	Add total P in precip
		CASTNET	Wet and dry dep of NO ₃ , NH ₄ , SO ₂ , SO ₄	
		NJADN	PCBs, PAHs in gas, aerosol and precip (discontinued)	Re-start SOC sampling
Forsythe NWR, NJ	Rural/ coastal	NADP NTN	Precip: Ca Mg K Na NH ₄ NO ₃ Cl SO ₄ H pH conductivity	
Lewes, DE	Rural/ coastal	NADP AIRMON	Precip: Ca Mg K Na NH ₄ NO ₃ Cl SO ₄ PO ₄ pH Conductivity	Add total P in precip Add CASTNET site Start SOC sampling or re-start at Delaware Bay NJADN site. Add speciated Hg sampling (NADP MTN or similar) and MDN
New Brunswick, NJ	suburban	NADP/MDN	Precip: Ca Mg K Na NH ₄ NO ₃ Cl SO ₄ H pH conductivity Total Hg	
		DRBC	PCBs in gas, aerosol and precip	
		NJDEP	VOCs, carbonyls, speciated PM _{2.5} , speciated Hg	Start PAH sampling via the DNREC protocols
Valley Forge, PA	Rural/ suburban	NADP/MDN	Precip: Total Hg	
		PADEP Acid rain	Ca Mg K Na NH ₄ NO ₃ Cl SO ₄ pH spec cond	
Camden, NJ	Urban	NJDEP	VOCs, carbonyls, speciated PM _{2.5}	Re-start speciated Hg sampling and add an MDN site

Site	Site type	Agency or program	Current analytes	Recommended additions
				here or at another suitable site within Camden
Camden, NJ (RU Camden Campus)	urban	DRBC	PCBs, PAHs in gas, aerosol	Install precip sampler
Chester, NJ	suburban	NJDEP	VOCs, carbonyls, speciated PM2.5, speciated Hg	
		NJADN	PCBs, PAHs in gas, aerosol, precip (discontinued)	
Northeast Philadelphia Airport, PA (Grant & Ashton)	Urban/suburban	DRBC	PCBs in gas, aerosol (discontinued)	
		City of Phil.	O ₃ , speciated PM2.5	Add major ions here or a similar urban Philadelphia location
Swarthmore, PA	suburban	PADEP	VOCs, TSP metals, PM10	
		DRBC	PCBs, PAHs in gas, aerosol (discontinued)	
MLK Blvd, Wilmington, DE	urban	DNREC	VOCs, carbonyls, TSP metals, PAHs, Dioxins & furans	
Route 9, Delaware City, DE	industrial	DNREC	VOCs, carbonyls, TSP metals, PAHs, Dioxins & furans	
Lums Pond SP, Summit, DE	rural	DNREC	VOCs, carbonyls, TSP metals, PAHs, Dioxins & furans	
		DRBC	PCBs in gas, aerosol	
Killens Pond, Felton, DE	rural	DNREC	VOCs, carbonyls, TSP metals, PAHs, Dioxins & furans	
Seaford, DE	suburban	DNREC	VOCs, carbonyls, TSP metals, PAHs, Dioxins & furans	
Tuckerton, NJ	Rural/coastal	NJADN	PCBs, PAHs in gas, aerosol (discontinued)	
Pinelands, NJ	rural	NJADN	PCBs, PAHs in gas, aerosol (discontinued)	
Delaware Bay, near Cape May Courthouse, NJ	rural	NJADN	PCBs, PAHs in gas, aerosol (discontinued)	Restart SOC sampling (alternatively, start

Site	Site type	Agency or program	Current analytes	Recommended additions
				SOC sampling at Lewes, DE)
Alloway Creek, NJ	rural	NJADN	PCBs, PAHs in gas, aerosol (discontinued)	
Over-water site (Brown Shoal Light or Brandywine Shoal Light)	Over-water	NOAA PORTS	none	Add NADP NTN MDN CASTNET and SOC sampling

6. How implemented Network would improve ability to address management issues

A very specific list of **Management Issues and Monitoring Needs** was identified in Section 2 of this report. This section summarizes how participation in the Pilot Study process has helped to improve management coordination and data exchange capacity. Actual implementation of enhancements to the existing network would improve regional capacity to address these issues and meet a variety of user needs at local, state and federal scales.

Pilot Study Process:

- Study participation has fostered a stronger partnership among contributing agencies and research institutions, and helped to identify common objectives, complementary programs and enhancements that meet multiple user objectives.
- The self assessment process for the region has stimulated a more integrated approach to water resource management that spans resource compartments, better connects river management with coastal management, and identifies opportunity for improved data exchange.
- The Delaware Pilot Steering Committee was fortunate to include the Executive Director of MACOORA, which in turn led to some start up funding by MACOORA for enhanced water quality data exchange in the region. In particular, work is underway for a “one stop shop” portal, known as the Delaware Estuary Watershed to Ocean Observing System. The Pilot process has helped to develop a regionally strong alliance between MACOORA IOOS interests and federal agency NWQMN interests—both of which are components to the President’s Action Plan.
- Two workgroups were established to help frame out a regional water quality monitoring designs that have direct import for the National Design: Wetlands and Atmospheric Deposition Resource Compartments.
- The Study process helped to position the Delaware Basin Partners to put together a competitive proposal in response to NOAA Funding Opportunity, NOS-CSC-2008-2001072, “ Implementation of Regional Integrated Ocean Observing Systems ”.

Major Management Issues:

- Implementation of network enhancements would advance several top priority science and management issues (as identified in early 2005 Estuary Science Conference and late 2005 NOAA-supported Workshop): **Contaminants; Tidal Wetlands; Physical-chemical-**

biological linkages; Nutrient System Dynamics; and Better data coordination, compatibility, quality, sharing, access and archiving.

- In 2006 Brigadier General Grisoli, North Atlantic Division Commander of the ACOE and Chairman of the Delaware River Basin Commission, convened a Coordination Summit with all federal agencies with a natural resource footprint in the Delaware River Basin. One of the two priority coordination issues identified at that forum focused on monitoring infrastructure. Participation in the Pilot Study process and identification of specific infrastructure enhancements significantly advances this strategic DRBC initiative.
- Coordination with Pilot Study representatives in other parts of the country offered insight into alternative resource management business models, some of which could be adapted to this region as it explores new ways of effecting environmental quality improvements.
- Lastly, it is hoped that the final Pilot Report will be a vehicle to engage regional policy makers on ways to enhance the water quality monitoring network and the value added of doing so.

7. Interactions with MACOORA and MARCOOS

The Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA) is the IOOS Regional Association for the Mid-Atlantic. The region spans the 1,000 km of coastline from Cape Hatteras to Cape Cod, and includes five subregions that represent the major bays, harbors and sounds. MACOORA is operated through the University of Delaware. MACOORA is the IOOS planning organization for the Mid Atlantic, providing a forum for user engagement and priority setting. MACOORA regularly sponsors an annual regional membership meeting, and has recently reinstated the successful user meetings in each of the five sub-regions. MACOORA sponsored a dedicated workshop on coastal inundation in 2007, and is **planning a second dedicated workshop on water quality in 2008**. The Delaware Estuary Watershed to Ocean Observing System (DEWOOS), as it develops, will use these and other MACOORA-sponsored venues to facilitate user interactions. MACOORA organized working groups in user engagement, new products, data management, and education/outreach will be leveraged as forums to share lessons learned throughout the region.

MACOORA's Regional Coastal Ocean Observing System (RCOOS) is operated through Rutgers University. The Mid Atlantic Regional Coastal Ocean Observing System (MARCOOS) is designed to meet regional user needs initially focused on (1) Maritime Safety-Search And Rescue and (2) Ecological Decision Support – Fisheries. A secondary MARCOOS mission is to provide regional scale datasets and model forecasts to MACOORA's five subregional observing systems. **The subregional observing systems, in turn, provide enhanced local products for user needs that include water quality and coastal inundation.**

DEWOOS is one of the five subregional ocean observing systems in MACOORA and is operated through the Delaware River Basin Commission (DRBC). As a MACOORA subregional observing system, DEWOOS not only leverages the strong linkages to both MACOORA and MARCOOS, it also contributes datasets and model forecasts back to the full region. MARCOOS and DEWOOS are both observing system implementing organizations, the first for the regional observation network, and the second for the subregional enhancements necessary to meet specific user needs in the Delaware River and Estuary Watershed. MACOORA sponsored user workshops have indicated that user needs are very local, but

mechanisms that drive critical events, like storms, occur on the regional level. This led to the design concept of the regional observing system, MARCOOS, providing data and forecasts of the storms at the regional level to the subregions that would locally enhance the datasets to produce the specific local products required by users. Based on initial interactions with the water quality user community, we expect a similar strategy to emerge from the MACOORA water quality workshop in 2008, since many water quality issues are dealt with at the state and county level.

MARCOOS and DEWOOS will have significant data sharing capabilities by design. The HF radars proposed by DEWOOS will be operated within the MARCOOS regional HF Radar network, directly contributing data to MARCOOS themes for (1) Maritime Safety – SAR and (2) Ecological Decision Support – Fisheries. DEWOOS will further leverage the MACOORA DMAC team to ensure that datasets are consistent throughout the region and nationally. The MACOORA Data Management and Communication Team (DMAC) team includes Eoin Howlett as chair, Dan Holloway, Dave Ullman for data validation, Josh Kohut as the DMAC representative for education, and John Wilkin as the DMAC representative for modeling. The MACOORA DMAC team is available for leveraging by MARCOOS and all five subregionals.

MARCOOS Satellite: Leveraging off the MARCOOS Satellite effort, DBOS will have access to a suite of real-time remote sensing products. The satellite data will be collected with existing L-band and X-Band receiving stations at Rutgers. For over a decade these systems have seamlessly provided data for the eastern seaboard. To ensure data availability, there is an automated backup system already operating in collaboration with the University of Maine. Rutgers has delivered satellite imagery in real-time to many users in the Northeast (70% from general public judged by web domain name). This component of MARCOOS includes real-time satellite data from the international constellation of satellites accessed through the MARCOOS data management system for distribution in near real-time. Through all three years of the program the regional satellite sea surface temperature and water mass products will be sustained and made available to the modeling partners for assimilation, the outreach patterns for targeted products, and the general public through the MARCOOS website. Products will be adjusted, as needed, based on user feedback.

MARCOOS Glider Operations. The DEWOOS glider effort will leverage the significant investment in glider AUV experience and infrastructure in the MAB, including the ONR Glider Technical Center at Rutgers University and the DoD MURI project. Investments by the Navy in the MA glider infrastructure (approximately \$10M) enable MARCOOS to propose a sustained glider presence at a reasonable cost. The ONR Glider Center also provides the infrastructure for glider command and control. From this center, Rutgers has flown gliders 35,608 kilometers underwater since October 2003 which represents 275,756 vertical casts of data. In addition to infrastructure, the MARCOOS effort will be conducting routine glider missions from Cape Cod to Cape Hatteras. These data provide far-field observations surrounding the DEWOOS domain.

The web-based portal for integrating water-quality data in the Delaware Basin study area will serve as a model for MACOORA stakeholders and other IOOS sub-regions. A one-stop shopping for available data will provide stakeholders with efficient means of obtaining water-quality and quantity data for modeling and management decisions. The upgrades to existing real-time monitoring stations in watersheds above the head of tide, estuaries, and coastal waters will provide timely, consistent, comparable data streams to users in for modeling and predictive capabilities.

8. Cost estimates

The Delaware Pilot has spent considerable effort in estimating costs as part of a parallel effort to respond to NOAA Funding Opportunity, NOS-CSC-2008-2001072, "Implementation of Regional Integrated Ocean Observing Systems". These data were used to help determine *annual cost of monitoring beyond Network design as determined by local needs* cells in Table 7 below.

Table 9. Cost Estimates for Current Monitoring and Filling Gaps.

These estimates are for preliminary budget purposes. More extensive cost estimates are dependent on final Interagency Workgroup contaminant and biological refinement workgroup lists.

Environmental component	Annual cost of existing monitoring as specified by Network design	Annual incremental costs of monitoring needed to fill gaps	Annual cost of existing monitoring beyond Network design as determined by local needs and local experts	Incremental costs needed to bring extra monitoring to Network specifications
Estuaries	\$457,400	\$200,000	\$3,600,000	\$0
Nearshore/Offshore	\$2,000,000	\$10,000,000	\$0	\$0
Great Lakes	NA	NA	NA	NA
Rivers	\$50,000 (1 location 4X/yr at HUC 6 site)	\$1,000,000 (5 HUC 8 head of tide locations)	\$2,650,000	\$0
Ground water	Significant Monitoring Underway	National Design not specified	\$550,000	
Atmospheric deposition	\$1,391,900	\$884,675	\$0	\$0
Wetlands	\$20,000	\$186,750	\$500,000	\$0
Beaches	Undetermined	Undetermined	Undermined	Undetermined
Data Management	Data Exchange Development Underway	\$200,000	\$0	\$0

9. Summary and major conclusions

As indicated in Section 6 of this report, the Study process is already bearing fruit in enhancing regional capacity to address management issues and exchange water quality information among a wide array of agencies, research institutions, and user interests. This section focuses on some of the findings and conclusions of the gap analysis process, with an eye toward a final synthesis product for consideration by National Water Quality Monitoring Council, the Advisory Committee on Water Information and federal policy makers concerned with implementing the National Design.

- Pilot assessments led directly to re-evaluation of specific components of the National Design (eg., detection limits for nutrients, tiered approaches to national design, compilation of master contaminant list) and case study application of ideas to better integrate IOOS and NWQMN national direction(s).
- Pilots offered more specific ground truthing of design options for resource components that are still in the national refinement process. In the case of the Delaware Pilot, there are very specific recommendation that relate to the ultimate design of the Wetlands and Atmospheric Depositions resource components.
- A preliminary estimate of costs to fill gaps is provided, but it warrants a revisit based on final decision-making relative to criteria for biology and contaminants.
- There is significant monitoring underway in all three pilots, but there are gaps relative to the national design in terms of number of sites, sampling frequency, and the need for additional analytes.
- The Delaware Pilot has determined that one HUC 6 river site is insufficient to characterize freshwater inflow to the estuary. We recommend discharge and contaminant loads at the Schuylkill River just south of Philadelphia, PA, the Maurice River in Cumberland County, NJ, and the Christina River in Delaware be monitored as well.
- Suspended and bed sediment monitoring data are infrequent and need significant upgrading to meet Network needs.
- The Delaware Pilot suggests that the National Design for the nearshore coast (which relies on monthly or quarterly routine sampling) may be insufficient to characterize responses that occur on the order of days. Since nutrients are being monitored as driving factor for phytoplankton blooms (and resulting low DO levels), it is suggested that routine remote sensing (satellite and/or aircraft) be used to identify episodic phytoplankton blooms and upwelling conditions that may relate to elevated nutrient conditions. Sampling for nutrients should be targeted to those times and locations where knowledge of nutrient levels is most critical.
- Some consideration of linking assessment metrics to “core” indicators should be incorporated as part of the national design. The Delaware Pilot provides specific examples in the wetland tiered design. This will facilitate not only comparison of subpopulations within the Delaware System, but also allow for comparisons among wetland systems nationally.

Appendix I: Pilot Study Partners Information

1. Primary contact person:

Robert A. Tudor, Deputy Executive Director, Delaware River Basin Commission
PO Box 7360, 25 State Police Drive, West Trenton, NJ 08628-0360

2. Key study partners (with institutional affiliations and clear statements of interest):

A Steering Committee (SC) consisting of representatives from DRBC, Federal, State, and academic entities decided to respond to the request for a Letter of Interest by the NWQMC for a Pilot Inventory study in support of the NMN. The SC decided that the DRBC should be the lead agency in the Pilot Study effort because it has jurisdiction over the entire basin and regulates water quality. The SC reached out to others—many who participated in the Rutgers Workshop in 2005—and came up with a plan to conduct a detailed inventory of water-quality monitoring in the DRB from April 2007 to January 2008.

Table 1. Steering Committee Members, Affiliations, and Commitment.

Member	Affiliation	Commitment
Robert Tudor	Delaware River Basin Commission (DRBC)	Chair
Rick Kropp	U.S. Geological Survey NJ Water Science Center (USGS)	USGS Liaison
Jeff Fischer	U.S. Geological Survey NAWQA (USGS)	NAWQA Liaison
Jon Kushwara	U.S. Environmental Protection Agency (USEPA)	USEPA Liaison
R. Scarborough	National Oceanographic and Atmospheric Association (NOAA) DE Dept. of Natural Resources and Env. Control (DNREC)	NERRS and DNREC Liaison
Ed Santoro	Delaware River Basin Commission (DRBC)	Inventory
Eric Vowinkel	NWQMC Methods and Data Comparability (MDCB)	Methods
Paul Morton	NJ Water Monitoring Coordination Council (NJWMCC)	Data Exchange
Danielle Kreeger	Partnership for the Delaware Estuary	Wetlands
Leslie McGeorge	NJ Depart. of Environmental Protection (NJDEP):	NJWMCC
Jonathan Sharp	U. Delaware (UDEL) College of Marine and Earth Studies	Estuaries, Acad.
Scott Glenn	Rutgers Univ. Institute of Marine & Coastal Sciences (IMCS)	Coastal, Academia
Lisa Totten	Rutgers University Cook College	Atmos., Academia

3. Description of any on-going collaboration among study partners such as data sharing efforts or cooperative data management efforts.

Historically, successful cooperation exists among the four states in the drainage basin through the Delaware River Basin Commission and coordinated management among the three estuary region states and EPA through the Delaware Estuary Program. Through this program, a Comprehensive Conservation and Management Plan (CCMP) and a Monitoring Action Plan

were prepared for the Delaware Estuary (<http://www.delawareestuary.org/>). Development of this pilot would significantly advance Action Items M4, M5 and M6 of that CCMP. The DRBC with its member States have set up advisory committees for the Basin such as: Flood, Information Management, Monitoring, Regulated Flow, Toxics, Water Management and Water Quality Advisory Committees. The Monitoring Advisory Committee of DRBC member States, the Federal government and other stakeholders will be a key coordinating entity for this project.

The Estuary Program (PDE) also operates the 21-member Science and Technical Committee (STAC) which includes representatives from DRBC, USGS, NOAA, and the states. The STAC provides broad-based peer review and technical support for CCMP implementation (www.DelawareEstuary.org) and ensures overall science and management activities are well-coordinated and informed by the latest science.

On 7/20/06, Major General Grisoli (Federal DRBC Commissioner) convened a Federal Coordination Summit attended by high level representatives of FEMA, NPS, NWS, USDA, NRCS, USACOE, USEPA, USFWS, USGS, Office of Surface Mining, FERC and States. Monitoring coordination was one of three priority focus areas, with specific objectives of evolving from discrete to increased real-time monitoring, effecting improved comparability among methods and using modeling and other tools to better target monitoring efforts.

The Delaware River Basin NAWQA Study (<http://nj.usgs.gov/nawqa/delr/>) has recently completed a water quality assessment of the Delaware River Basin which included stream, sediment, and ecological monitoring. In addition to the data collected as part of this study, NAWQA compiled data from different State and Federal agencies within the basin. NAWQA will share data and assist in compilation and analysis of this and other data. Past collaborative efforts with the USDA Forest Service and the National Park Service have been highly successful

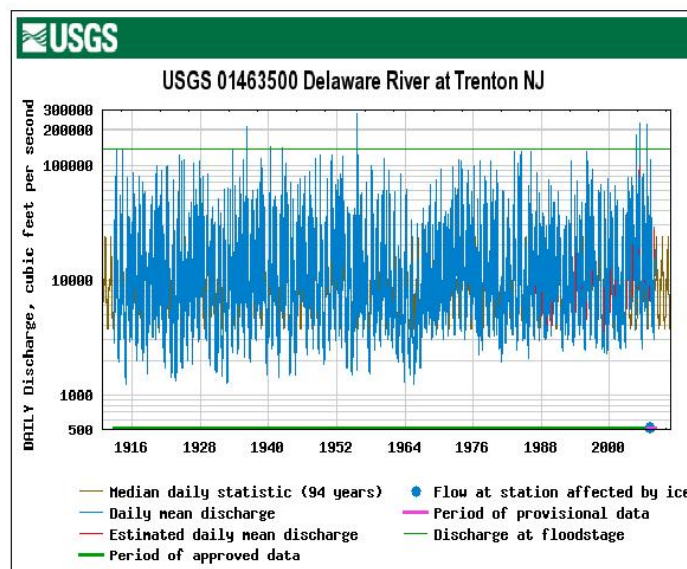
The Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA) is one of eleven such associations around the country that make up the Integrated Coastal Ocean Observing System (ICOOS) (<http://www.macoora.org/>). MACOORA ranges from Cape Cod to Cape Hatteras, covering five sub-regions (Massachusetts and Rhode Island Bays, Long Island Sound, New York Bight, Delaware Bay, and Chesapeake Bay) in nine states and the District of Columbia. MACOORA is a consortium of data providers and users from both private and public sectors that use, depend on, study and manage coastal environments and their resources. MACOORA was formed to ensure that all major stakeholders are involved in the design of the observing systems and the periodic evaluation of the system's performance.

The DRBC in cooperation with Rutgers University's Department of Environmental Sciences and Center for Environmental Prediction currently operate three air deposition monitoring stations located at Lums's Pond, DE, Camden, NJ and New Brunswick, NJ. Samples are collected to determine the flux of gaseous phase pollutants particularly PCBs and pesticides between surface waters and the atmosphere, dry and wet deposition. This network is being used as part of efforts to refine and implement TMDLs for PCBs in the Delaware River and Bay as well as for long-term trend monitoring of toxic pollutants.

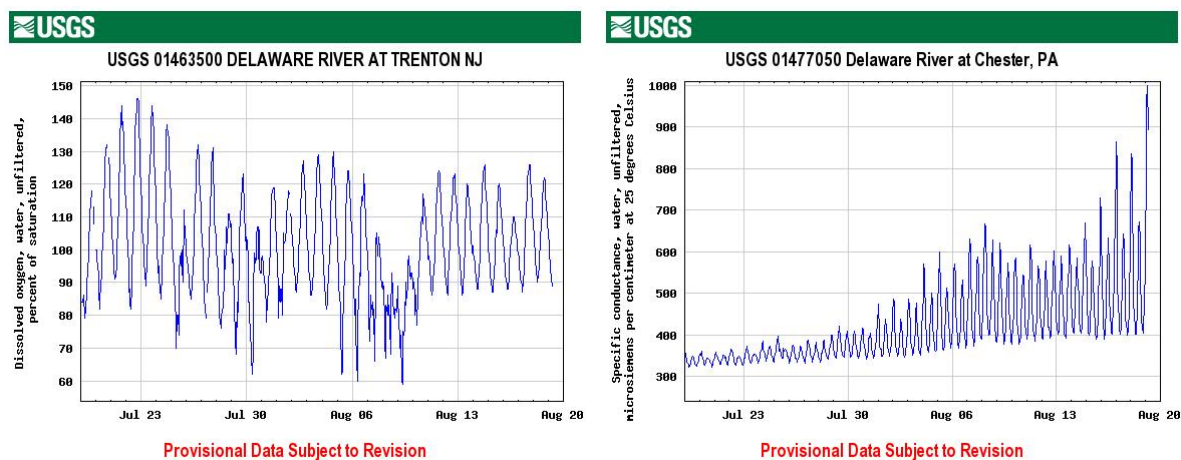
New Jersey Water Monitoring Coordination Council (NJWMCC), a consortium of State, Federal, local, and private monitoring entities (<http://www.nj.gov/dep/wms/>) was formed to address monitoring issues in NJ. NJDEP has a grant from the USEPA for \$750K to develop a Water Data Exchange (WQX) to: (1) integrate water-quality data; (2) streamline/simplify data transfer; (3) provide timely access to water-quality data between NJDEP, USEPA/STORET and USGS/NWIS. NJDEP is working closely with the Consortium of University for the Advancement of Hydrological Sciences (CUAHSI) (<http://www.cuahsi.org/>) and USEPA/ESAR

programs to optimize WQX schema architectures. CUAHSI has funding from and National Science Foundation grant to link Federal databases into a common portal. To the extent possible, the DRB Pilot study will coordinate and WQX activities with WaterOneFlow web services and graphical water assessment products.

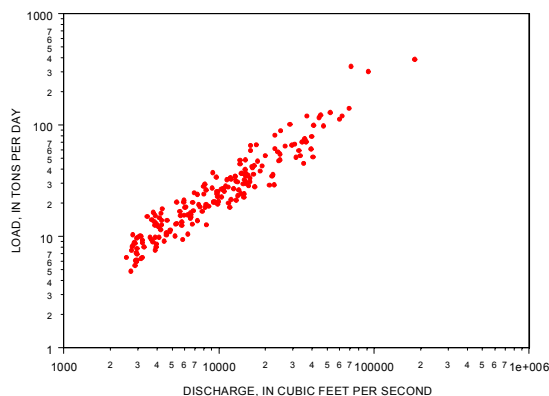
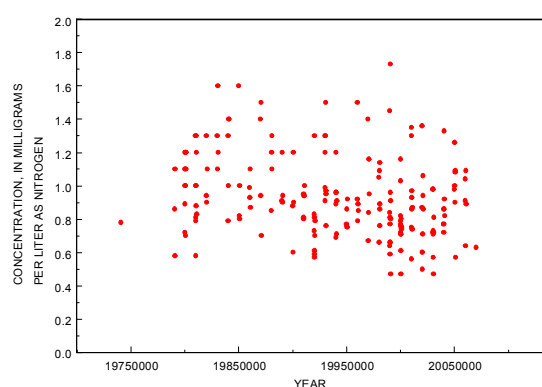
Appendix II. Surface Water Flow Data for Delaware River at Trenton, NJ.



Appendix II-1. Mean daily flow at the Delaware River at Trenton gage 1913-current.



Appendix II-2. Real-time measurements over a 31-day period in July-August, 2007 for (A) dissolved oxygen data at the Delaware River at Trenton site and (B) specific conductance at the Delaware River at Chester site

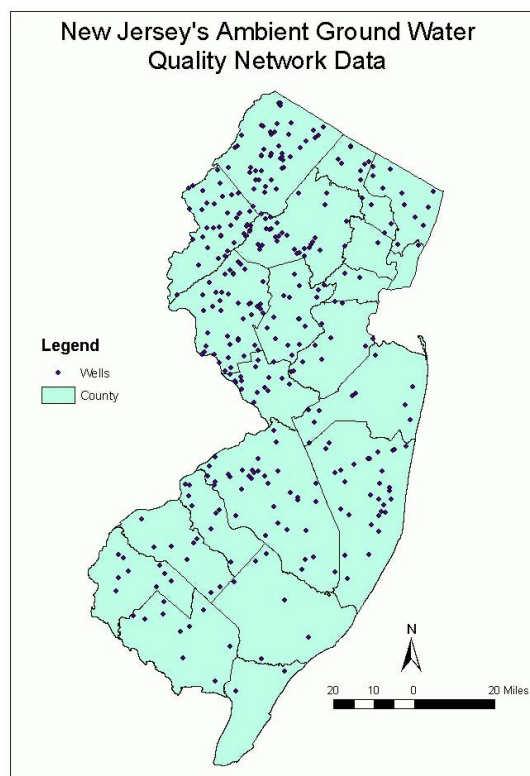


Appendix II-3. Nitrate plus nitrite monitoring at the Delaware River at Trenton site by: (A) date, and (B) load relative discharge.

Appendix II-4. Harmonic mean flows for major streams in the Delaware Basin, 1978 to 2002.

Tributary	USGS Station ID	Drainage Area in square miles	Harmonic mean flow at gage in cubic feet per second
DELAWARE RIVER AT TRENTON NJ	01463500	6,780	6,502
SCHUYLKILL RIVER AT PHILADELPHIA, PA	01474500	1,893	1,297
BRANDYWINE CREEK AT WILMINGTON, DE	01481500	314	258
MAURICE RIVER AT NORMA NJ	01411500	112	114
NORTH BRANCH RANCOCAS CREEK AT PEMBERTON, NJ	01467000	118	107
NESHAMINY CREEK NEAR LANGHORNE, PA	01465500	210	105
ASSUNPINK CREEK AT TRENTON NJ	01464000	91	77
CROSSWICKS CREEK AT EXTONVILLE NJ	01464500	82	72
WHITE CLAY CREEK NEAR NEWARK, DE	01479000	89	60
CHESTER CREEK NEAR CHESTER, PA	01477000	61	56

Appendix III: Ground Water Quality Data

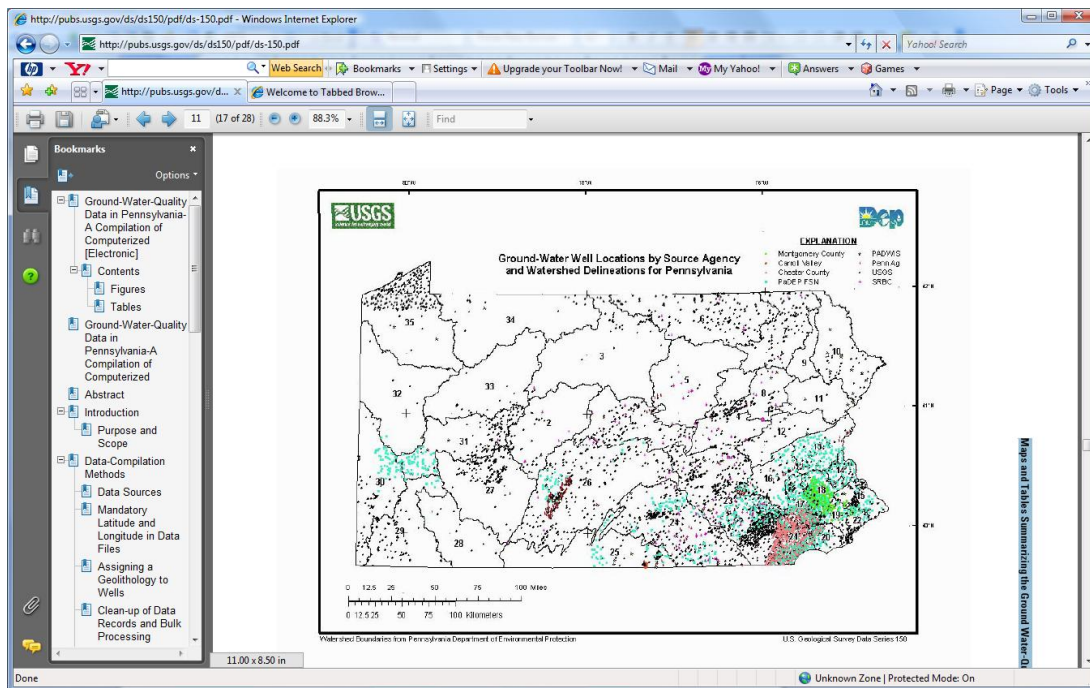


Appendix III-1. Location of 150 wells in the NJ Ambient Ground Water Quality Monitoring Network.

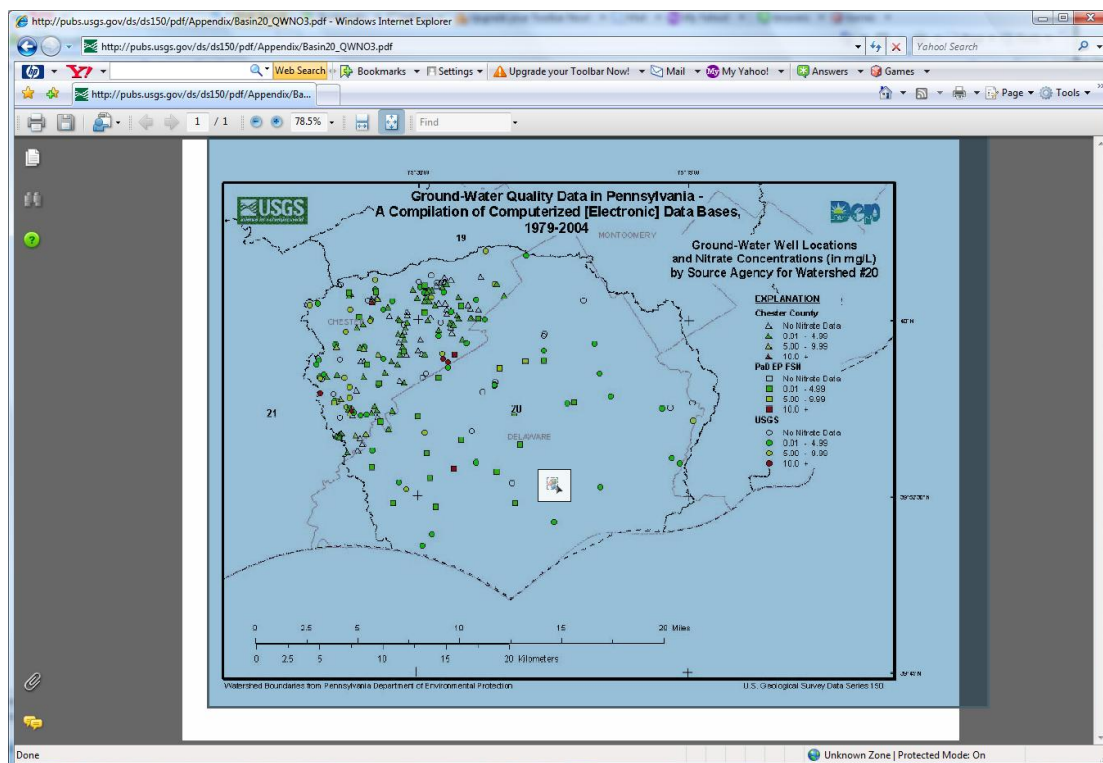
Appendix III-2. Metadata for NJ Ambient Ground Water Quality Monitoring Network.

(<http://www.nj.gov/dep/njgs/geodata/dgs05-2.htm>)

Field parameters and Major ions	METADATA	DOWNLOAD	65KB
Metals	METADATA	DOWNLOAD	55KB
Nutrients	METADATA	DOWNLOAD	48KB
Pesticides	METADATA	DOWNLOAD	35KB
Radionuclides	METADATA	DOWNLOAD	43KB
Volatile Organic Compounds (VOC)	METADATA	DOWNLOAD	50KB



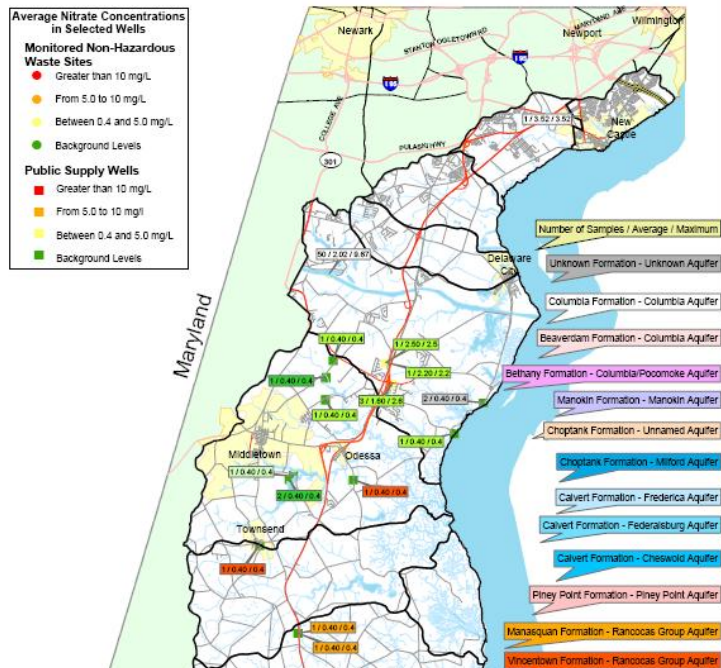
Appendix III-3. Location of ground-water monitoring in Pennsylvania



Appendix III-4. Locations of ground-water monitoring in Pennsylvania in Watershed 20.

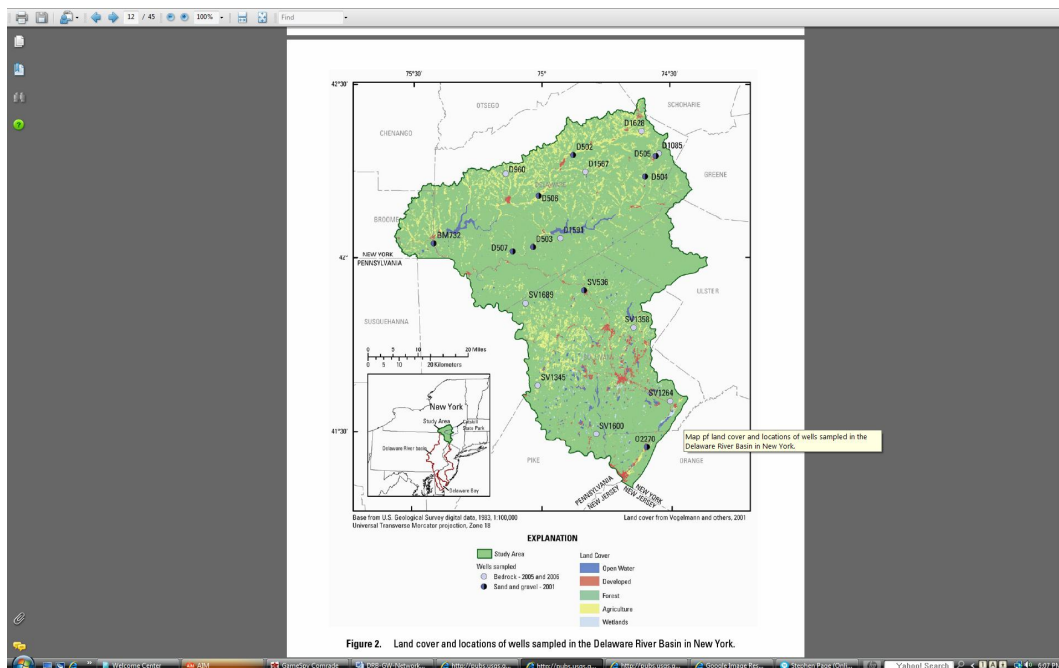
http://pubs.usgs.gov/ds/ds150/pdf/Appendix/Basin20_QWNO3.pdf

Map 2.5-7 Nitrate Concentrations in Selected Wells



Appendix III-5. Wells sampled for water-quality in the Delaware River Basin Watershed in Delaware.

<http://www.dnrec.delaware.gov/NR/rdonlyres/B0A71664-8B11-417F-B754-5430725D9549/0/257Nitrate.pdf>



Appendix III-6. Wells sampled in the Delaware River Basin in New York.

(<http://pubs.usgs.gov/sir/2004/5118/SIR2004-5118.pdf>)

